Approved For Release 2008/01/04 : CIA-RDP78T05439A000400280057-5

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ANALYSIS OF THE PHYSICAL ENVIRONMENT AT THE TYUMEN' ICBM COMPLEX

Section I. INTRODUCTION

The physical environment in the vicinity of the Tyumen' ICBM complex has been analyzed and the engineering-geology conditions at each launch site are presented. The purpose of this study and similar studies of other complexes is to provide data that can be used to determine the criteria used by the Soviets in selecting locations for their ICBM sites and to evaluate how terrain conditions probably influenced construction of the complex and will influence its physical vulnerability. Knowledge of Soviet terrain requirements for ICBM sites may aid in locating additional sites in a complex and in finding new complexes.

The Tyumen' complex at the time of study consisted of one possible Type III hard site, three Type IIc soft sites (one perhaps abandoned), and the necessary support facilities. The complex is approximately 18 nautical miles south of Tyumen' and the Sverdlovsk - Tyumen' Railroad. It is constructed on the southern edge of the West Siberian Plain in the drainage basin of the Pyshma River. Terrain in the vicinity of the complex consists of a nearly flat, gently sloping plain covered by numerous swamps and lakes; it is drained by sluggish, meandering streams tributary to large, low-gradient rivers. The area, which has a dry, continental climate characterized by warm summers and cold winters, lies about 190 nautical miles south of the permafrost zone; average seasonal frost penetration is about 4 feet, with a maximum depth of about 7 feet. Snowfall is light, but the snow cover generally persists from early November through mid-April. Earthquakes have not been recorded in the area.

Section II. ENGINEERING GEOLOGY

Analysis of the physical environment at the Tyumen' ICBM complex is based on a study of Soviet publications in the fields of geology and soils, modified by interpretation of TALENT-KEYHOLE photography. Detailed information is presented in the accompanying table and graphics.

Components of the Tyumen' complex are situated on the higher, better drained parts of a nearly flat, silty sand plain that has numerous marshes, swamps, and lakes. The silty sand (Unit 4), which is generally less than 25 feet thick but in places as much as 70 feet thick, is present throughout the mapped area except along the Pyshma and Bateni Rivers. This silty sand layer is overlain in places by peat (Unit 1), 1 to 6 feet thick; by alluvial mixtures of sand, silt and clay (Unit 2), about 40 feet thick; and by lacustrine silty clay (Unit 3), 3 to 6 feet thick. It is underlain throughout the mapped area by calcareous silty clay (Unit 5) about 35 to 70 feet thick, silty sand (Unit 6) about 35 feet thick, and marine plastic clay (Unit 7) more than 600 feet thick.

Abundant natural construction material of silty sand, suitable for fine aggregate if washed and screened, is easily available. Small lenses of gravelly sand and sandy gravel in the silty sand layer provide minor amounts of fine gravel if screened. Rock and coarse gravel are not available within the area. Most natural materials, excluding peat, are suitable for fill. Good construction timber is obtainable from numerous nearby scattered stands of dense forest.

The silty sand is generally poorly suited to unsuited as a natural foundation for surface structures within 5 feet of the surface because of its frost susceptibility; at greater depths, it is suitable when drained. The silty clay is almost equally frost susceptible and is only fair to poor below depth of frost action. Valley bottoms (Unit 2) are poorly suited for natural foundations, as they are subject to flood. Swamps and marshes (Unit 1) are unsuited because of organic soils and the difficult drainage problems. Excavation of the unconsolidated sediments is easy with power equipment; ground water is generally encountered at depths of less than 20 feet, however, and as a result of the spring snowmelt and infrequent heavy summer rains, it may rise to near the surface. Excavation walls require strong support to prevent slumping. Surface and subsurface drainage is good on porous silty sand but poor on silty clay and plastic clay. Seismic velocities in silt and sand layers range from 1,000 to 6,500 feet per second below the water table, mostly 1,500 to 3,000 above. In plastic clay they range from 1,000 to 9,000 feet per second, and in peat, from a few hundred to 1,100 feet per second.

Large* quantities of good-quality surface water are perennially available from the Pyshma River and larger lakes. Variable quantities of good- to poor-quality surface water are available from small tributary streams, swamps, marshes, and small lakes; the sources may become dry in summer and usually freeze solid in winter. Small to moderate quantities of fair- to poor-quality ground water are perennially available from stream alluvium (Unit 2) at depths of less than 40 feet. Small to meager quantities of fair-quality ground water are perennially available from silty sand beds (Units 4 and 6) at depths of less than 120 feet. Ground water from wells sited in marine plastic clay at depths of generally more than 120 feet is usually brackish or saline.

LAUNCH SITE 1

Launch Site 1, a Type IIc soft site possibly abandoned, is situated on a slight rise on a nearly flat plain about 8.5 nautical miles south-southeast of the small village of Onakhino on the Pyshma River. Relief within 1 nautical mile is about 40 feet. Vegetation in the western half of the site area is cutover forest consisting of shrubs and a few scattered trees; the eastern half is dense evergreen forest with some deciduous trees. Tree types include Scotch pine up to 70 feet tall and 18 inches in diameter, and white birch, Siberian spruce, and European aspen up to 60 feet tall and 12 inches in diameter. Pine and spruce are good as construction timber; birch and larch are fair to good, but aspen is poor.

The site is on a layer of silty sand (Unit 4), about 15 to 25 feet thick, underlain by beds of calcareous silty clay (Unit 5) about 45 feet thick, silty sand (Unit 6) about 35 feet thick, and marine plastic clay (Unit 7) more than 600 feet thick. The silty sand layer provides a good to fair foundation below the depth of frost action, about 5 feet, if it is dry and compacted; it is poorly suited when wet or subject to frost action. Foundations are unsuited on the unstable, saturated beds of calcareous silty clay, silty sand, and marine plastic clay. Surface and subsurface drainage in the porous silty sand layer is rapid to the depth of the water table, usually about 10 to 15 feet from the surface but less than this during spring snowmelt and from infrequent heavy summer rains. Small to meager quantities of good- to fair-quality ground water are available from the silty sand layer at depths of about 10 to 25 feet, and from the silty sand bed at depths from about 60 to 110 feet. Below depths of about 120 feet, ground water is usually brackish or saline. Sources of perennial surface water are lacking immediately adjacent to the launch site.

Excavation is easy with power equipment; however, walls require very strong support to prevent slumping. At depths below the water table, extensive drainage would be necessary and very difficult. The silty sand is suitable for fine aggregate if washed and screened, and minor quantities of fine-sized gravel may be locally available within the silty sand layer. Rock is absent, but good construction timber is available from the dense forest adjacent to the site on the east. Seismic velocities above the water table range mostly from 1,500 to 3,000 feet per second, and from 1,000 to 6,500 below.

* For explanation of water terms, see Engineering Geology table footnote ***

LAUNCH SITE 2

Launch Site 2, also a Type IIc soft site, is on a slight rise about 5.5 nautical miles south-southwest of Onakhino. Relief within 1 nautical mile is about 40 feet. Vegetation is mostly dense forest similar to that at Launch Site 1, with patches and strips of cutover forest in various stages of regrowth.

Other environmental aspects at Site 2 are similar to those at Site 1 except that the surface layer of silty sand (Unit 4) is about 50 to 70 feet thick, and the underlying bed of calcareous silty clay (Unit 5) is about 70 feet thick.

LAUNCH SITE 3

Launch Site 3, also of Type IIc configuration, is situated on a low ridge about 4.5 nautical miles south-southeast of the village of Onakhino. Relief within 1 nautical mile is approximately 60 feet. Vegetation within about 0.5 nautical mile is dense forest similar to that at Launch Site 1. Beyond this there are strips and patches of cutover forest with regrowth except to the northwest, where it is predominantly marsh.

Other environmental aspects of the site are similar to those at Launch Site 1 except that the surface layer of silty sand (Unit 4) is about 45 feet thick, and the calcareous silty clay (Unit 5) is about 65 feet thick.

LAUNCH SITE 4

A possible Type III hard site, Launch Site 4 is on a slight rise approximately 7.5 nautical miles south-southwest of the village of Onakhino. Relief within 1 nautical mile is about 25 feet. In addition to marsh vegetation in areas northeast and east of the site, vegetation nearby includes cutover forest with strips and patches of dense, mature trees similar to those at Launch Site 1.

Excavation is greater than 90 feet require heavy grouting of the bed of silty sand (Unit 6), as it is an artesian aquifer. Other environmental aspects of the site are similar to Launch Site 1 except that the surface layer of silty sand (Unit 4) is about 40 feet thick and the calcareous silty clay (Unit 5) is about 50 feet thick.

Section III. SUMMARY

The Tyumen' ICBM complex is on a flat, poorly drained plain that is free of permafrost, and is situated in an area where earthquake activity has not been reported. A study of the terrain negates any environmental factor as a major consideration in selecting this location for a complex. The only major similarity between launch sites is that all are on the higher lying parts of the poorly drained plain. On the basis of geologic conditions, locations of the launch sites and support facilities were as well selected as possible for an area that has a generally poor environment. All of the four deployed sites -- two Type IIc soft sites, one possibly abandoned Type IIc soft site, and one possible Type III hard site -- rest on slight rises of porous silty sand. The silty sand provides good to fair foundations for surface structures below the depth of frost action (about 5 feet) when it is dry; however, it provides poor foundations when wet, a condition that exists when the shallow water table rises during spring snowmelt and from infrequent heavy summer rains. The soft, saturated materials encountered in excavations are unsuited as foundations for hard, silo-type sites; this is especially true of the silty sand bed about 100 feet from the surface, which is an artesian aquifer and requires heavy grouting in preparing stable foundations. Excavation of the soft soils is easy with power equipment; however, walls require very strong support to prevent slumping, and drainage of deep excavations is very difficult. Silty sand, suitable as fine aggregate if washed and screened, is readily available, but importation of all rock and gravel from distant sources is necessary for the construction of large structures. Good timber for construction uses is readily available. Adequate perennial water supplies are obtainable from shallow ground-water sources as well as from the Pyshma River and large lakes.

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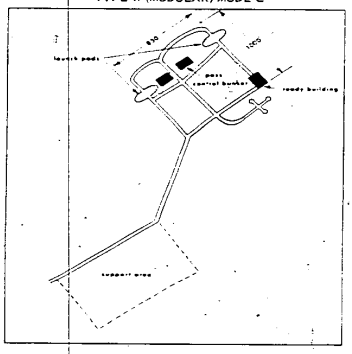
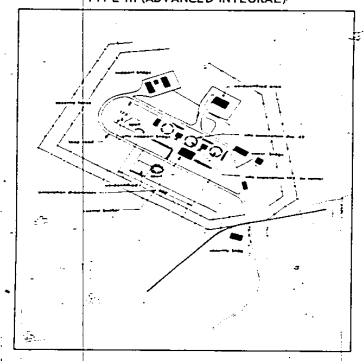
LAUNCH SITE CONFIGURATIONS

TYPE II (MODULAR) MODE C



TYPE III (ADVANCED INTEGRAL)



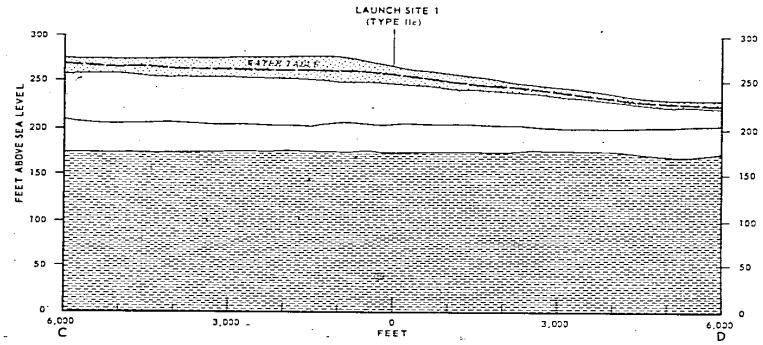
NOTE: THE CONFIGURATIONS SHOWN ARE CHARACTERISTIC PATTERNS ONLY, AND ARE NOT NECESSARILY EXACT REPRESENTATIONS OF THE TYUMEN' COMPLEX.

DIAGRAMMATIC GEOLOGIC CROSS SECTIONS AT TYUMEN' ICBM LAUNCH SITES

FOR LOCATION OF AREAS DIAGRAMMED, SEE MAP ON PAGE 6. FOR EXPLANATION OF GEOLOGIC UNITS, SEE TABLE ON PAGE 7.

HORIZONTAL SCALE 1:20,000
VERTICAL EXAGGERATION 20X

LAUNCH SITE 1 (TYPE IIc)



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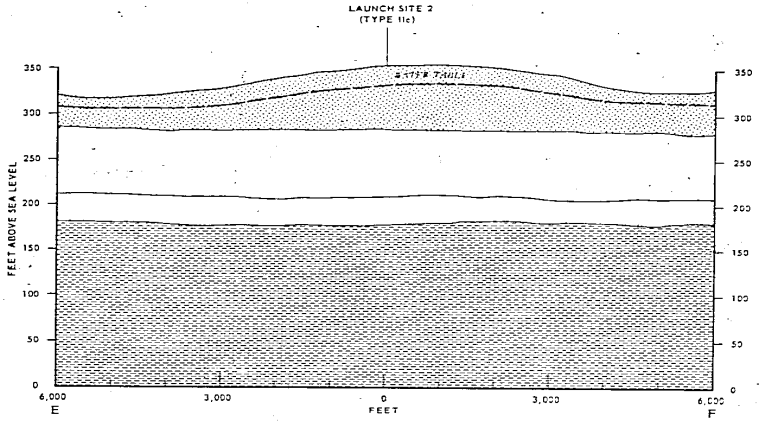

RELIABILITY OF CROSS SECTIONS

DATA ON SEQUENCE, THICKNESS, AND COMPOSITION OF LAYERS ARE BASED ON AVAILABLE GEOLOGIC LITERATURE AND ON INFORMATION REGARDING PHYSIOGRAPHIC FEATURES OF THE GENERAL AREA OF THE SITES, MODIFIED BY TALENT-KEYHOLE PHOTOGRAPHY. DATA ON SEQUENCE AND COMPOSITION OF THE LITHOLOGIC UNITS ARE VERY RELIABLE. THICKNESS OF LAYERS IS RELIABLE WITHIN ±15 FEET. ELEVATIONS AT THE SITES ARE BASED ON AIR TARGET CHART SERIES 200, SHEETS 0156-2CA AND 0156-2S. RELIABILITY OF ELEVATION INFORMATION IS ±33 FEET.

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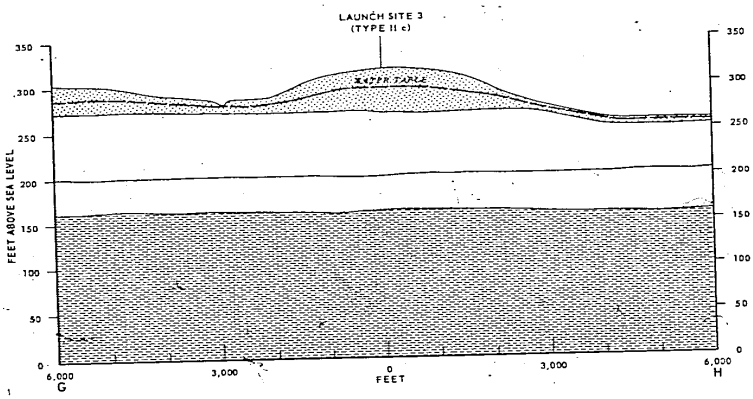
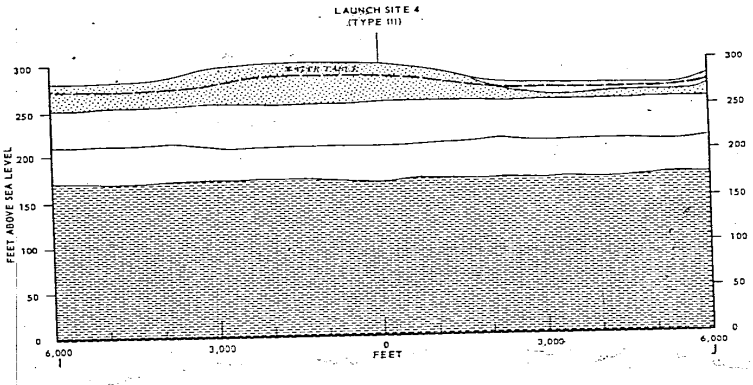
DIAGRAMMATIC GEOLOGIC CROSS SECTIONS
(CONTINUED)





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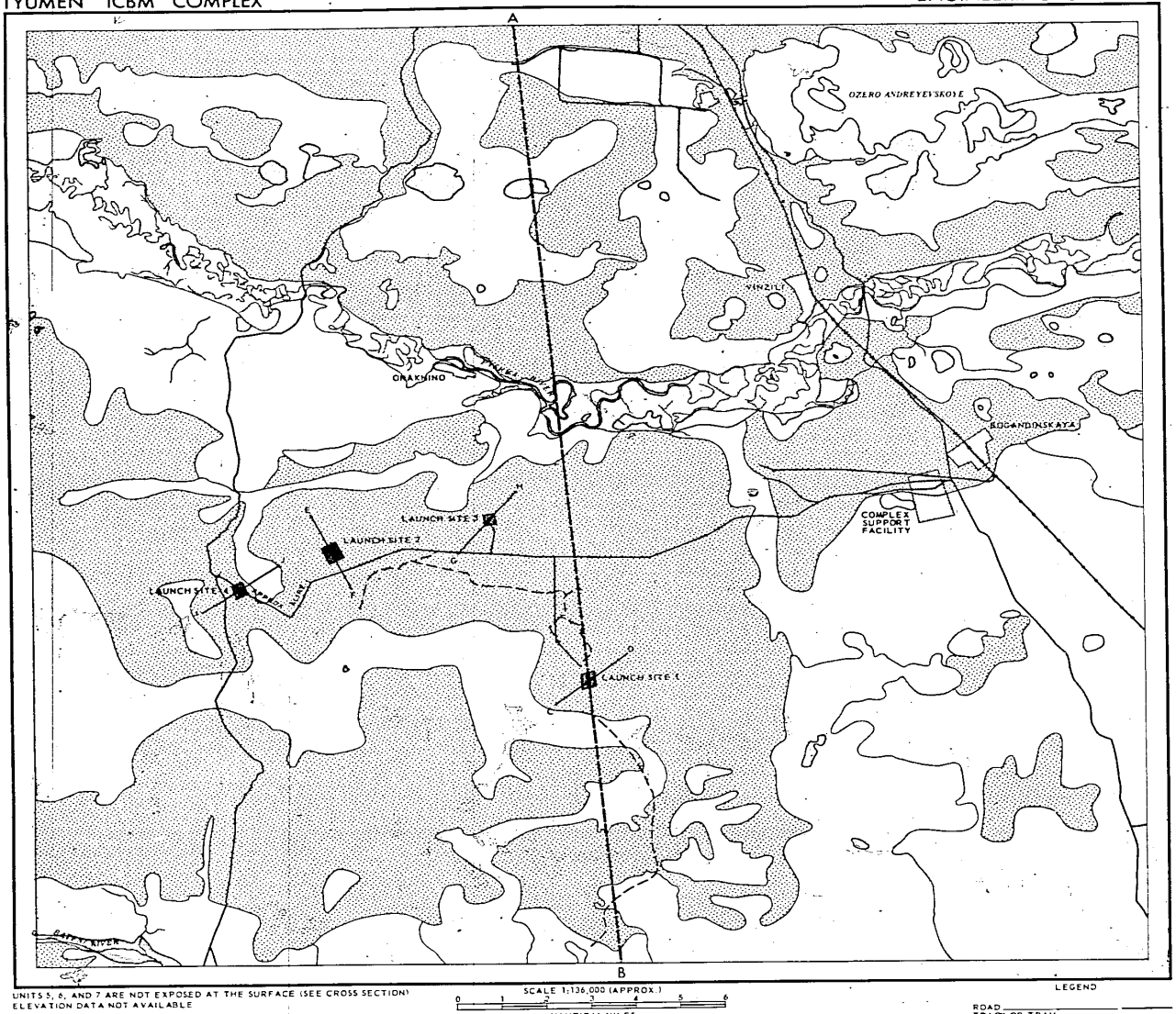
TYUMEN' ICBM COMPLEX

ENGINEERING GEOLOGY

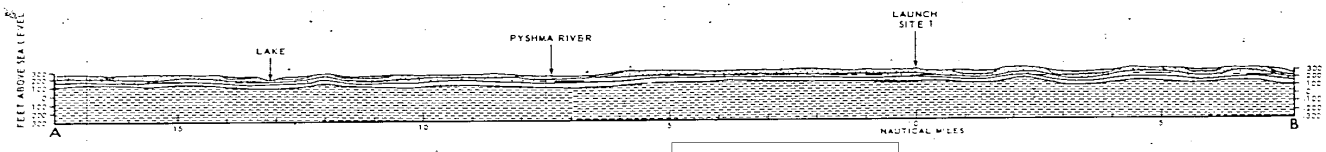


UNITS 5, 6, AND 7 ARE NOT EXPOSED AT THE SURFACE (SEE CROSS SECTION)
ELEVATION DATA NOT AVAILABLE

SCALE 1:136,000 (APPROX.)
0 1 2 3 4 5 6
NAUTICAL MILES

LEGEND
ROAD
TRACK OR TRAIL
RAILROAD, 5'0" GAGE
SINGLE TRACK
DOUBLE TRACK
RAILROAD, NARROW GAGE

DIAGRAMMATIC GEOLOGIC CROSS SECTION
VERTICAL EXAGGERATION 12X



TYUMEN' 6

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ENGINEERING GEOLOGY

UNIT	DESCRIPTION (Units arranged in stratigraphic order -- surface to [illegible] of 200 ft. or more)	SUITABILITY FOR CONSTRUCTION			GROUND-WATER SUPPLY*		SEISMIC VELOCITIES (Given for upper layer only; for underlying layers, use seismic velocities of respective units)	
		Foundations	Excavations	Natural Materials	Aquifers	Quantity, Quality, and Siting	Material	Velocity (in feet per second)
1	Peat (Pt**), 1 to 6 ft. thick, containing matted roots in upper part. Underlain by either silty clay (CL) (Unit 3), 3 to 6 ft. thick, or silty sand (SM) (Unit 4), 2 to 25 ft. thick. Underlain by beds of silty clay (CL) (Unit 5), 35 to 70 ft. thick; silty sand (SM) (Unit 6), about 35 ft. thick, and plastic clay (CH) (Unit 7), more than 600 ft. thick. In marshes, bogs, and swamps, some of which are either quarried for peat or drained for cultivation.	Soft Sites: Unsuited because of high water table and unstable soils. Fair to poor if area drained, peat removed, and coarse materials used for backfill. Water table at or near surface. Hard Sites: Unsuited on beds of unstable saturated soils. Drainage very difficult.	Hand tools mostly inadequate because water table at or near surface; power equipment required. Slopes generally unstable because soils saturated.	Peat unsuited except for insulation. Silty sand suitable for fine aggregate and fair for fill if washed and screened, difficult to develop because of high water table. No rock available, but some construction timber in swamps.	Aquifer peat layer to depths of about 6 ft. Aquifer of silty sand (Unit 4) about 10 to 30 ft. below the surface. Artesian aquifers of silty sand (Unit 6) about 85 to 120 ft. below the surface, and of sandy layers in saline plastic clay (Unit 7) at various depths greater than 120 ft. Water from wells in artesian aquifers rise nearly to surface.	In summer, large*** quantities available from peat beds adjacent to lakes and rivers, meager to small quantities available from small, scattered peat beds. In winter, meager quantities available. Quality poor because of high bacterial contamination and organic content. Meager to small quantities of fair-quality water available from silty sand of Units 4 and 6. Meager to small quantities of brackish to saline water available from silty sand in saline plastic clay of Unit 7. In places, upward migration of salt water contaminates upper aquifers and peat beds; locally salt-water springs. Siting easy but water points subject to flooding in summer. Recharge in peat good in summer, poor in winter; that of sandy aquifers, fair.	Peat	A few hundred to 1,100
2	Silty sand (SM), sandy silt (ML), silty clay (CL), and plastic clay (CH) in alternating beds of unknown thickness and sequence; total thickness about 40 ft. Overlain by randomly distributed organic silt (OL) and organic clay (OH), 1 to 3 ft. thick. Underlain along unit margins by silty sand (SM) (Unit 4), 2 to 25 ft. thick. Underlain throughout by beds of silty clay (CL) (Unit 5), silty sand (SM) (Unit 6), and plastic clay (CH) (Unit 7) to depths of more than 600 ft. Forms grass-covered flood plains of the Pyshma and Iset Rivers.	Soft Sites: Unsuited because of inundation by rivers 40 to 60 days annually, beginning about April 15. Depth of frost penetration about 3 to 7 ft. Saturated soils very unstable. Water table generally less than 10 ft. from surface. Hard Sites: Same as Unit 1.	Excavation by hand tools easy to water table, difficult below; easy with power equipment. Walls require strong support.	Organic silt and clay unsuited for fill, silty sand fair, plastic clay fair to poor, and sandy silt and silty clay poor. Silty sand suitable for fine aggregate if washed and screened. Rock and construction timber unavailable.	Aquifers of silty sand and some sandy silt generally less than 10 to 40 ft. below the surface. Along margins of Unit, aquifer merges with silty sand (Unit 4) at depths of about 10 to 30 ft. Artesian aquifers of silty sand (Unit 6) and sandy layers in saline plastic clay (Unit 7) same as described in Unit 1.	Small to moderate quantities from upper sand and silt layers; yield per well from a few hundred to several thousand g. p. d. (gallons per day); fair- to poor-quality water with high bacterial contamination near settlements and swamps. Quality and quantity of water available from aquifers of Units 4, 6, and 7 are the same as described in Unit 1. Siting easy but water points subject to flooding in summer. Recharge fair.	Silty sand, sandy silt, and silty clay Plastic clay	1,000 - 6,500 As much as 9,000
3	Silty clay (CL), 3 to 6 ft. thick; covered in local depressions by a plastic clay (CH) and organic clay (OH) layer, generally 1 to 2 ft. thick. Underlain by silty sand (SM) (Unit 4), 2 to 25 ft. thick, and by beds of silty clay (CL) (Unit 5), silty sand (SM) (Unit 6), and plastic clay (CH) (Unit 7) to depths of more than 600 ft. Forms terrace surfaces, generally cultivated but with patches of forest.	Soft Sites: Very poor on silty clay within 4 ft. of surface because of frost action; fair to poor below. Good to fair on underlying silty sand when drained; poor when wet. Water table 3 to 12 ft. below surface. Hard Sites: Same as Unit 1.	Excavation by hand tools easy to water table, difficult below; easy with power equipment. Walls require strong support.	Silty clay and plastic clay poor for fill, organic clay unsuited. Underlying silty sand of Unit 4 suitable for fine aggregate if washed and screened, fair for fill. No rock available, but timber suitable for construction readily obtainable.	Aquifers of silty sand (Units 4 and 6) and sandy layers in saline plastic clay (Unit 7).	Meager to small quantities from Units 4, 6, and 7 are the same as described above in Unit 1.	Silty clay with plastic clay and organic clay	1,000 - 9,000
4	Silty sand (SM), in places with thin layers of poorly graded sand (SP) and small lenses of gravelly sand (SP) and sandy gravel (GP), mostly 2 to 25 ft. thick, in some places 40 to 70 ft. thick. Underlain by beds of silty clay (CL) (Unit 5), silty sand (SM) (Unit 6), and plastic clay (CH) (Unit 7) to depths of more than 600 ft. Forms forested and cultivated terraces and gently sloping plains.	Soft Sites: Fair to poor on silty sand within 5 ft. of surface because of frost action, good to fair below 5 ft. when dry. Poor when wet. Very poor on underlying silty clay bed. Water table generally less than 20 ft. below surface. Hard Sites: Same as Unit 1.	Excavation by hand tools easy to water table, difficult below; easy with power equipment. Walls require strong support.	Silty sand suitable for fine aggregate if washed and screened. Gravel mostly in small sizes and limited supply; requires screening. Sandy gravel, poorly graded sand, and gravelly sand good for fill, silty sand fair for fill. No rock available, but timber suitable for construction readily obtainable.	Aquifers of silty sand, and in some places thin layers of sand and gravel, less than 20 ft. from the surface to as much as 70 ft. deep locally. Artesian aquifers of silty sand (Unit 6) at depths generally less than 85 ft., to depths of about 120 ft. from the surface. Artesian aquifers of sandy layers in saline plastic clay (Unit 7) at various depths greater than 120 ft.	Meager to small quantities of good- to fair-quality water from shallow wells; bacterial contamination low except near settlements, bogs, swamps, and marshes; reported yield per well less than 2,000 g. p. d. Meager to small quantities of fair-quality water available from silty sand of Unit 6. Meager to small quantities of brackish to saline water available from sand beds in saline plastic clay of Unit 7. In places upward migration of salt water contaminates upper aquifers. Siting easy. Recharge fair.	Silty sand with sand, gravelly sand, and sandy gravel	1,000 - 6,500; mostly 1,500 - 3,000 above water table
5	Calcareous silty clay (CL), 35 to 70 ft. thick, loess-like in the upper part, and sandy in the lower part; with numerous silty sand and sandy silt lenses. Grades downward into silty and clayey sand. Underlain by silty sand (SM) (Unit 6), about 35 ft. thick, and plastic clay (CH) (Unit 7), more than 600 ft. thick. Occurs near surface in poorly drained depressions; underlies entire mapped area.	Soft Sites. Very poor. Soil occurs near surface only in poorly drained areas; soils saturated and difficult to drain. Hard Sites: Same as Unit 1.	Excavations difficult; power tools and equipment required in saturated soils. Strong wall support necessary to contain unstable soils.	Silty clay poor for fill. Limited quantities of silty sand suitable for fine aggregate if washed and screened, fair for fill. No rock available.	Aquifers generally lacking in silty clay bed.	Meager quantities from silty clay bed. Siting easy. Recharge poor.	Silty clay	1,000 - 6,500; higher where very calcareous
6	Silty sand (SM), about 35 ft. thick, with some thin layers of silty clay (CL) and sandy silt (ML). Underlain by plastic clay (CH) (Unit 7) more than 600 ft. thick. Does not occur at surface; underlies entire mapped area.	Soft Sites: Not applicable; not exposed at surface. Hard Sites: Same as Unit 1.	Silty sand bed artesian aquifer. Excavations require grouting and strong wall support. Power tools and equipment required.	Silty sand suitable for fine aggregate if washed and screened, fair for fill. No rock available. Silty clay and sandy silt poor for fill.	Aquifer of silty sand bed about 35 ft. thick at depths of about 85 to 120 ft. Aquifers artesian; water rises to less than 20 ft. from surface.	Meager to small quantities available from silty sand. Water reportedly fresh, with no taste or odor; bacterial contamination low, and total dissolved solids about 500 to 1,000 p. p. m. (parts per million), but increases and becomes brackish with continued heavy pumping. Water in underlying sandy layers (Unit 7) brackish or saline. All wells artesian. In places, upward migration of salt water contaminates upper aquifers; contaminated aquifers yield brackish water. Siting easy. Recharge fair.	Silty sand	1,000 - 6,500
7	Marine plastic clay (CH), massive, more than 600 ft. thick with thin layers of sandy and silty clay (CL). Does not occur at surface; underlies entire mapped area.	Soft Sites. Not applicable; not exposed at surface. Hard Sites. Same as Unit 1.	Marine plastic clay bed contains artesian aquifers. Excavations require grouting and strong wall support. Power tools and equipment required.	Plastic clay poor for fill. Rock and aggregate not available.	Sandy layers in saline plastic clay at depths of from 120 ft. to 600 ft. Aquifers artesian.	Meager to small quantities of brackish or saline water from sandy layers. All wells artesian and yield 4,000 g. p. d. or more. Salinity of ground water increases with depth. Aquifers at depths of about 800 ft. have from 3,000 to 23,000 p. p. m. total dissolved solids. In places, upward migration of salt water contaminates upper aquifers; source of salt-water springs. Siting easy. Recharge fair.	Plastic clay	3,000 - 9,000 mostly near upper end of range

*SURFACE-WATER SUMMARY. Large quantities are available from the Pyshma River, which has a mean discharge of about 1 billion g. p. d.; dissolved solids near 200 to 500 p. p. m., depending on the season, salinity is 19 to 86 p. p. m., increasing with discharge. Maximum discharge occurs between 15 and 25 April, when flow is 10 to 20 times greater than the rest of the year; minimum discharge is in February, when river is ice covered and flow is less than 1.3% of the annual discharge. Ice first appears in river by end of October and forms a continuous sheet by 10 November; river is covered by ice an average of 167 days per year. Ice breakup starts 5 to 15 April and continues for 6 to 8 days as spring flood begins. Period of flooding is 40 to 60 days. Quantities are variable from small intermittent streams, which are frozen solid for 25 to 75 days in winter and become dry for 15 to 30 days in summer. Large quantities are available from numerous large lakes present in the area, with depths generally less than 20 feet; during droughts some lakes become dry and during wet periods their areal extent increases tremendously, converting large areas of forest into swamp. The lakes are poorly suited for water supply, as they are bordered by swamps or marshes and contain water that is high in bacterial contamination; total dissolved solids are generally less than 900 p. p. m., although some lakes and marshes are perennially brackish or saline because of salt water springs.

**The nomenclature and accompanying soil symbols used in this table are in accordance with those defined and described in the Unified Soil Classification System, Corps of Engineers, U.S. Army T.M. No. 3-357; Waterways Experiment Station, Vicksburg, Mississippi, March 1953.

***Large: more than 1,500,000 g. p. d.; moderate: 150,000 to 1,500,000 g. p. d.; small: 15,000 to 150,000 g. p. d.; meager: less than 15,000 g. p. d. Quantities based on assumed multiple well development.

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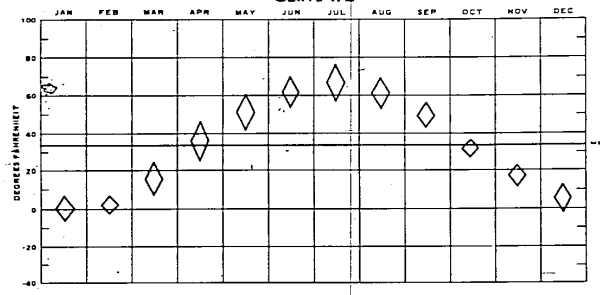
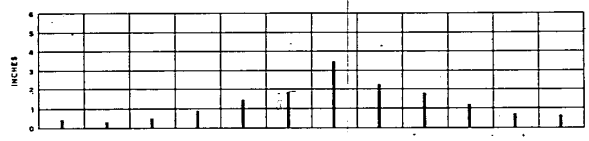
CLIMATE



MONTHLY TEMPERATURES

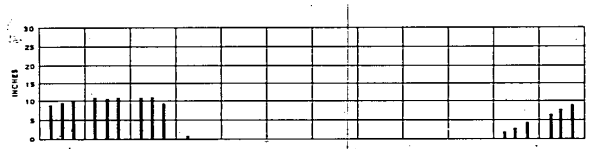
MEAN DAILY MAXIMUM
MEAN TEMPERATURE
MEAN DAILY MINIMUM
ABSOLUTE MAXIMUM 98°F
ABSOLUTE MINIMUM -58°F

MEAN ANNUAL TEMPERATURE 33°F

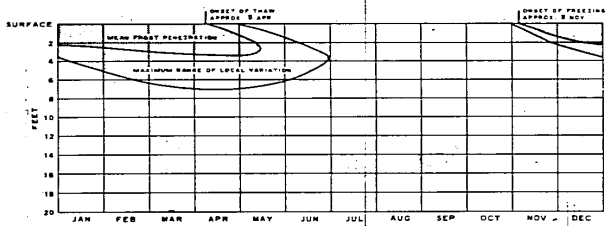


MEAN MONTHLY PRECIPITATION

MEAN ANNUAL PRECIPITATION 15 INCHES

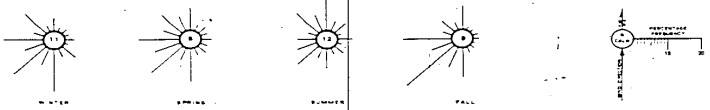


MEAN SNOW DEPTHS
(BY 10-DAY PERIODS)



FROST DEPTHS

SURFACE WIND DIRECTIONS



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DEPARTMENT OF DEFENSE
WASHINGTON, D. C., 20301

SAO/PC 270/1-1-64

ANALYSIS OF THE PHYSICAL ENVIRONMENT AT YEDROVO ICBM COMPLEX

THIS STUDY IS ONE OF A SERIES OF ALL-SOURCE INTELLIGENCE REPORTS ON ICBM COMPLEXES IN THE U.S.S.R. ADDITIONS WILL BE PUBLISHED AT INTERVALS AS INFORMATION BECOMES AVAILABLE.

This study is based on information available as of June 1963.

SOVIET ICBM COMPLEXES

PREPARED BY
DEFENSE INTELLIGENCE AGENCY
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ANALYSIS OF THE PHYSICAL ENVIRONMENT AT THE YEDROVO ICBM COMPLEX

Section I. INTRODUCTION

The physical environment in the vicinity of the Yedrovo ICBM complex has been analyzed and the engineering-geology conditions at each launch site are presented. The purpose of this study and similar studies of other complexes is to provide data that can be used to determine the criteria used by the Soviets in selecting locations for their ICBM sites and to evaluate how terrain conditions probably influenced construction of the complex and will influence its physical vulnerability. Knowledge of Soviet terrain requirements for ICBM sites may aid in locating additional sites in a complex and in finding new complexes.

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The Yedrovo complex at the time of study consisted of 1 hardened launch site, 6 soft sites, [redacted]. The complex is located about 165 nautical miles southeast of Leningrad on forested, glaciated terrain composed of flat to gently sloping plains with numerous steeply sloping, elongated hills, and numerous marshes, swamps, and lakes. The complex area is drained by many small, sluggish streams. The climate is moderate with mild summers and cool winters. Snowfall is light with the snow cover generally persisting from late November through early April. The area lies about 375 nautical miles south of the permafrost zone; seasonal frost penetrates to a maximum depth of about 4 feet and does not constitute a problem in construction except in structures with shallow foundations. This region is not subject to earthquake damage.

Section II. ENGINEERING GEOLOGY

Analysis of the physical environment at the Yedrovo ICBM complex is based on a study of Soviet publications in the fields of geology and soils modified by interpretation of TALENT-KEYHOLE photography. Detailed information is presented in the accompanying table and graphics.

The glaciated, hummocky terrain of the Yedrovo area is underlain by bedrock of massive shale (Unit 6). A wedge of layers of limestone, cavernous dolomite, and shale (Unit 5), which thickens to the east, overlies the massive shale bed except in the northwestern part of the mapped area, where it is absent. Dolomite is exposed at the surface in the southwestern part of the mapped area, and limestone and dolomite are exposed at the surface in the central part. These exposures form inconspicuous ridges with sinkholes present on the back or dip slopes. Glacial deposits of gravel, sand, silt, and clay overlie bedrock in most places. Clayey glacial till (Unit 4), a heterogeneous mixture of coarse- and fine-grained material, occurs as steeply sloping, elongated hills (moraines) as much as 250 feet high. Glacial deposits of stratified coarse- to fine-grained sand with some layers of sandy gravel (Unit 3) form kames as much as 50 feet high, and deposits of well-graded sandy gravel form eskers as much as 130 feet high. Lacustrine silty sand (Unit 2) as much as 25 feet thick forms gently sloping plains and overlies clayey glacial till and sands and gravels. Numerous depressions in the hills and plains have swamps, marshes, and peat bogs (Unit 1), and commonly contain small, shallow to deep lakes.

Abundant quantities of coarse aggregate are available in the central and western part of the mapped area from gravels of eskers, and abundant quantities of fine aggregate are available throughout the mapped area from sands of eskers, kames, and plains. Bedrock of limestone and dolomite well suited for building stone, riprap, aggregate, and fill is available in the central and southwestern part of the mapped area. Clayey glacial till well suited for fill is common throughout the area. Timber suitable for construction is readily available and consists of Norway spruce and Scotch pine of fair to good quality, and aspen and white birch, generally of fair to poor quality.

Natural foundations for soft sites are excellent on limestone and dolomite where not fractured or cavernous, and good on shale. Natural foundations below the level of frost penetration, about 4 feet, are good on sandy gravel of kames and eskers, good to fair on sand of kames, fair on clayey glacial till, and fair on silty sand of plains. Natural foundations for hard sites are generally good on bedrock of limestone, dolomite, and shale, and fair to good on moraines of clayey glacial till. Excavation above the water table by power equipment would be easy in glacial deposits but difficult below; strong wall support is needed. Excavation in bedrock requires power equipment, with drilling and blasting operations necessary in dolomite and limestone beds. Drilling and blasting operations in bedrock are hampered by caverns in dolomite beds and fractures in limestone beds. Excavations in bedrock would require mostly minor wall support.

Good- to fair-quality surface water in abundant quantities is perennially available from numerous deep lakes in the mapped area. Poor-quality water in large* to small quantities is perennially available from numerous small lakes and streams. Ground water of fair to poor quality in small to large quantities is perennially available from caverns in dolomite and fractures in limestone. Meager to moderate quantities of fair- to good-quality water are available from sand and silt aquifers throughout the area except near peat bogs, swamps, and marshes, where quantities are meager to large and quality is mostly poor.

LAUNCH SITE 1

Launch Site 1, a Type IIb site, is located about 14 nautical miles southwest of Yedrovo on a silty sand plain adjacent to moraines of clayey glacial till. Relief within 1 nautical mile of the site probably does not exceed 50 feet. Vegetation is mostly dense forest of spruce mixed with birch, pine, aspen, and in an adjacent swamp, willow. The trees are as much as 60 feet tall and 18 inches in diameter.

The plain on which Launch Site 1 is situated consists of unconsolidated, stratified silty sand (Unit 2) overlying clayey glacial till (Unit 4), which totals about 15 feet in thickness. Bedrock is only about 15 feet thick, predominantly dolomite with some limestone beds (Unit 5), overlying a massive soft shale bed (Unit 6) which extends to depths of more than 450 feet.

Surface drainage of the site is fair to good on the gently sloping terrain composed of porous sandy soils, but subsurface drainage is poor because of the low permeability of the underlying clayey glacial till (Unit 4). Small to moderate quantities of fair- to good-quality ground water are available from aquifers of sand layers, and meager to small quantities available from aquifers of silt layers. Small to large quantities are available from the dolomite and limestone beds; quality is fair to poor.

Stability of foundations for heavy surface structures is fair on silty sand if compacted and fair on clayey glacial till, below the depth of frost penetration. Foundation stability is good to excellent on bedrock of sound dolomite and limestone (Unit 5) and good on massive shale (Unit 6). Excavation in silty sand and clayey glacial till is easy with power equipment but hampered at depths of less than 10 feet by the shallow water table; walls require strong support to prevent slumping. Excavation in bedrock would require power equipment; drilling and blasting are necessary in dolomite and limestone beds and would be difficult in dolomite because of caverns. Walls require little or no support. Seismic velocities of the natural materials surrounding the site mostly range from 1,000 to 6,500 feet per second in sandy soils, 1,300 to 4,000 in clayey glacial till, 7,000 to 20,000 in dolomite and limestone, and 3,000 to 14,000 in massive shale.

Adequate sources for most natural construction materials are present within about 5 nautical miles. Bedrock of limestone and dolomite suitable for most construction uses is available underlying the site, and also to the northeast and southwest along surface exposures which form short, steep ridges. Gravel and sand suitable for aggregate and fill are available in abundant quantities from nearby kames and eskers. Spruce and pine timber that is fair to good for construction is readily available.

LAUNCH SITE 2

Launch Site 2, also of Type IIb configuration, is located about 6 nautical miles south of Yedrovo. Relief within 1 nautical mile of the site is about 130 feet. Vegetation is similar to that at Launch Site 1.

The site is situated on a moraine of clayey glacial till (Unit 4), about 10 to 40 feet thick, which overlies layers of limestone with dolomite, locally cavernous, and shale (Unit 5), to a depth of about 200 to 260 feet.

Surface drainage is good on the steeply sloping moraine, but subsurface drainage is poor because of the low permeability of the clayey glacial till. Small to large quantities of fair- to poor-quality ground water are available at depths of less than about 150 feet from limestone and dolomite layers.

Stability of foundations for heavy surface structures is fair on clayey glacial till (Unit 4) below the depth of frost penetration. Stability is good to excellent on bedrock of sound limestone and dolomite, and good on shale. The water table is at a depth of about 50 feet. Excavation in clayey glacial till would be easy with power equipment, but in bedrock of limestone and dolomite drilling and blasting would be necessary. Seismic velocities of natural materials surrounding the site mostly range from 1,300 to 4,000 feet per second in the clayey glacial till, and from 3,000 to 20,000 in the layers of limestone, dolomite, and shale.

Natural construction materials are similar to those at Launch Site 1, except that limestone and dolomite suitable for most construction purposes are exposed in ridges to the northwest and southwest.

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SITE 3

[redacted] located on an anticlinal ridge about 6 nautical miles west-southwest of Yedrovo. Relief within 1 nautical mile probably does not exceed 100 feet. Vegetation consists mostly of dense birch forest with some spruce, pine, and aspen intermixed. Trees are as much as 60 feet tall with diameters of 12 inches for birch and aspen, and 18 inches for spruce and pine.

This site is situated on a steep hill of predominantly dolomite with some limestone beds (Unit 5), about 20 to 50 feet thick, in places overlain by clayey glacial till (Unit 4), generally less than 20 feet thick. A massive, soft shale bed (Unit 6) underlies the limestone and dolomite and extends to depths of more than 450 feet.

Surface and subsurface drainage are good on the anticlinal ridge of dolomite and limestone. Meager quantities of fair- to poor-quality ground water are available from thin layers of cavernous dolomite, soft sandstone, and sand in the massive shale bed at depths of more than 150 feet.

Stability of foundations for heavy surface structures is good to excellent on sound limestone and dolomite, and fair on clayey glacial till below the depth of frost penetration. The water table is at a depth of about 150 feet. Excavation by power equipment would be easy in clayey glacial till, but walls would require support. Excavation of dolomite and limestone would be difficult because of caverns and fractures, and drilling and blasting would be required, but walls would require little or no support. Power operations in the massive shale bed would be mostly easy and walls would require some support. Seismic velocities of natural materials surrounding the facility mostly range from 1,300 to 4,000 feet per second in clayey glacial till, 7,000 to 20,000 in layers of limestone, dolomite, and shale, and 3,000 to 14,000 in massive shale.

Adequate sources for most natural construction materials are present within 1 nautical mile. Bedrock of limestone and dolomite suitable for most construction uses is available at, and adjacent to, the facility along surface exposures which form short, steep ridges. Abundant quantities of sand and gravel for aggregate and fill are available from kames and eskers to the south. Spruce and pine timber, fair to good for construction, is available within the dense birch forest surrounding the site.

LAUNCH SITE 4

Another Type IIb installation, Launch Site 4 is located on a steeply sloping hill about 8 nautical miles southwest of Yedrovo. Relief within 1 nautical mile is about 100 feet. Vegetation is similar to that at Site 3.

Launch Site 4 is situated on a moraine of clayey glacial till (Unit 4) about 5 to 25 feet thick which overlies layers of limestone, with dolomite, locally cavernous, and shale (Unit 5) to a depth of about 150 to 200 feet.

Surface drainage of the site is good on the steeply sloping moraine, but subsurface drainage is poor because of the low permeability of the clayey glacial till. Small to large quantities of fair- to poor-quality ground water are available at depths of less than about 200 feet from limestone and dolomite layers underlain by shale layers.

Stability of foundations for heavy surface structures is fair on clayey glacial till below the depth of frost penetration. Foundation stability is good to excellent on bedrock of sound limestone and dolomite layers, and good on shale layers (Unit 5). Excavation in clayey glacial till would be easy with power equipment but wall supports are required. In bedrock of limestone and dolomite, drilling and blasting operations would be necessary but excavation walls would require little or no support. The water table is at a depth of about 40 to 60 feet. Drainage and sealing of the water-bearing zone near the contact between the limestone and shale layers and dolomite and shale layers are necessary. Seismic velocities of natural materials surrounding the site mostly range from 1,300 to 4,000 feet per second in the clayey glacial till, and from 3,000 to 20,000 in layers of limestone, dolomite, and shale.

Adequate sources for most natural construction materials are present within 4 nautical miles. Limestone and dolomite suitable for most construction uses are available to the north, northwest, and south along surface exposures which form short, steep ridges. Abundant quantities of sand and gravel for aggregate and fill are available from kames and eskers to the north-northwest of the site. Timber of fair to good quality for construction use is abundant.

* For explanation of water terms, see Engineering Geology table footnote***

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LAUNCH SITE 5

Launch Site 5, a Type IIb site, is located on an undulating plain about 10 nautical miles west-southwest of Yedrovo. Relief within 1 nautical mile of the site probably does not exceed 40 feet. The surrounding forest is similar to that of Launch Site 4. Within the launch site area, the well-drained plains of coarse-grained soils are cultivated; poorly drained depressions have marsh and swamp vegetation of sphagnum mosses, reed grasses, willows, and alders.

Site 5 is situated on a kame of stratified, coarse- to fine-grained sand with some layers of sandy gravel (Unit 3), about 10 to 50 feet thick. The kame is underlain by massive shale (Unit 6) about 450 to 500 feet thick with thin layers of marl, cavernous dolomite, soft sandstone, and sand.

Surface drainage is fair to good on kames of porous, coarse-grained sandy soils, but subsurface drainage is poor because of the low permeability of the massive shale. Small to moderate quantities of fair- to good-quality ground water are available from sand and gravel aquifers at the base of the kames. Meager quantities of fair- to poor-quality ground water are available from thin layers of cavernous dolomite, soft sandstone, and sand within the massive shale bed to depths of about 500 feet.

Stability of foundations for heavy surface structures is good on sandy gravel, and good to fair on sands of kames below the depth of frost penetration. Foundation stability is good on the massive shale. Excavation of the stratified sands and gravels (Unit 3) is easy even with hand tools, but wall support is needed to prevent slumping. The water table lies near the contact of the massive shale bed at depths of about 10 to 50 feet. Considerable drainage is required near the contact zone of the sandy layers and bedrock. Excavation of the massive shale is easy with power equipment although some drilling and blasting may be required if hard, cavernous dolomite is encountered; some wall support is required. Drainage and sealing of any of the permeable beds of cavernous dolomite, soft sandstone, and sand are also necessary. Seismic velocities of natural materials surrounding the site mostly range from 700 to 6,500 feet per second in sands and gravels, and from 3,000 to 14,000 in massive shale.

Adequate sources for most natural construction materials could be developed within a distance of 5.5 nautical miles. Limestone and dolomite suitable for most construction uses are available within 5.5 nautical miles of the site along surface exposures which form short, steep ridges. Abundant quantities of sand and gravel suitable for aggregate and fill are available underlying, and adjacent to, the launch site. Timber of fair to good quality for construction use is readily available.

LAUNCH SITE 6

Launch Site 6 is also a Type IIb site, located about 21 nautical miles southwest of Yedrovo. It lies on a silty sand plain (Unit 2) adjacent to steep-sloping, elongated eskers (Unit 3) and peat depressions (Unit 1). Although on a plain, relief within 1 nautical mile of the site is about 75 feet because of the eskers. Vegetation consists of clusters of trees amid cultivated areas. In the peat depressions there are clusters of trees, shrubs, and grasses; the eskers are grass covered. The trees are mostly spruce, bog birch, and larch, and attain a height of 40 feet and a diameter of 12 inches. The shrub swamp vegetation includes willows and alders which grow to a height of 6 feet with diameters of 2 inches or less, reed grasses, and sphagnum mosses.

Site 6 is on a plain of stratified silty sand, about 10 to 15 feet thick, which overlies clayey glacial till (Unit 4) about 10 to 15 feet thick. Bedrock is alternating layers of soft shale and clay about 50 to 60 feet thick, underlain by cavernous dolomite beds (Unit 5), about 40 feet thick, that rest on massive shale (Unit 6).

Surface drainage is fair to good on the gently sloping terrain of porous sandy soils, but subsurface drainage is poor because of the low permeability of the underlying clayey glacial till. Ground water is available in small to moderate quantities from aquifers of sand layers, and meager to small quantities from silt layers (Unit 2); quality is fair to good. Larger quantities are available from caverns in dolomite and fractures in limestone (Unit 5); quality is fair to poor.

Stability of foundations for heavy surface structures is fair on silty sand if compacted, and fair on clayey glacial till below the depth of frost penetration. Foundation stability is good to fair on bedrock of shale and clay, and good to excellent on sound dolomite and limestone. Excavation in silty sand and clayey glacial till is easy with power equipment, but would be hampered at depths of less than 10 feet by the shallow water table; walls require strong support to prevent slumping. Excavation in bedrock of shale and clay would require power equipment; walls would require some support in shale, much support in clay. Drilling and blasting would be required in the dolomite and limestone; caverns in dolomite would hamper drilling and blasting operations, but walls would require little or no support. Seismic velocities of natural materials surrounding the site mostly range from 700 to 6,500 feet per second in the sandy soils, 1,300 to 4,000 in clayey glacial till, 3,000 to 14,000 in the shale and clay beds, and 7,000 to 20,000 in the dolomite and limestone beds.

Adequate sources for most natural construction materials are present within 3 nautical miles. Limestone and dolomite suitable for most construction uses are available to the west along surface exposures which form short, steep ridges. Additional exposures are located about 11 nautical miles to the east and northeast. Abundant quantities of gravel and sand suitable for aggregate and fill are available from eskers adjacent to the west side of the launch site. Some fair- to good-quality timber of spruce and pine is available from clusters of trees to the north and south of the launch site.

LAUNCH SITE 7

Launch Site 7, a Type IIb site, is located about 20 nautical miles west-southwest of Yedrovo. It lies in a valley adjacent to steep-sloping eskers (Unit 3) to the south and northeast and moraines (Unit 4) to the northwest. Relief within 1 nautical mile of the site is about 75 feet. Vegetation is primarily dense spruce and birch forest with intermixed pine and aspen.

Site 7 is situated in a valley of stratified silty sand (Unit 2), about 10 to 15 feet thick, which overlies clayey glacial till (Unit 4), about 10 to 15 feet thick. Bedrock is cavernous dolomite (Unit 5), about 10 to 20 feet thick, which rests on massive shale (Unit 6).

Surface drainage is fair to good on the gently sloping surface of porous sandy soils, but subsurface drainage is poor because of the low permeability of the underlying clayey glacial till. Water of fair to good quality could be obtained in small to moderate quantities from sand and gravel aquifers and in meager to small quantities from the silt layers (Unit 2). Larger quantities are available from caverns in dolomite beds and fractures in limestone beds (Unit 5), but the quality is fair to poor.

Stability of foundations for heavy surface structures is fair on silty sand if compacted, and fair on clayey glacial till below the depth of frost penetration. Foundation stability is good to excellent on bedrock of sound dolomite and limestone, and good on the massive shale. Excavation in silty sand and clayey glacial till is easy with power equipment but would be hampered by ground water at depths of less than 10 feet in valleys and 30 feet in eskers and moraines. Excavation walls require strong support to prevent slumping. Excavation in dolomite and limestone requires drilling and blasting, and would be hindered by caverns in dolomite beds. Walls in dolomite and limestone require little or no support. Excavation in shale with power equipment is generally easy, and walls require some support. Seismic velocities of natural materials surrounding the site mostly range from 700 to 6,500 feet per second in the sandy soils, 1,300 to 4,000 in clayey glacial till, 7,000 to 20,000 in the dolomite and limestone beds, and 3,000 to 14,000 feet per second in massive shale.

Natural construction materials are similar to those available at Site 6. Fair- to good-quality timber is readily available adjacent to the site.

LAUNCH SITE 8

Launch Site 8, the only Type III site in the complex, is located on a steeply sloping moraine about 11 nautical miles west-southwest of Yedrovo. Relief within 1 nautical mile is about 150 feet. The steeply sloping moraine is covered by dense forest of intermixed spruce, birch, pine, and aspen; gently sloping plains between moraines are cultivated.

The site is situated on the side of a steeply sloping moraine composed of clayey glacial till (Unit 4), about 25 to 40 feet thick, overlying bedrock of predominantly dolomite with some limestone beds (Unit 5), about 35 to 40 feet thick, in places with thin layers of marl and soft shale. The latter unit overlies a massive shale bed (Unit 6), 450 to 500 feet thick, which includes thin layers of marl, cavernous dolomite, soft sandstone, and sand.

Surface drainage is good on the steeply sloping moraine, but subsurface drainage is poor because of the low permeability of the clayey glacial till. Small to large quantities of fair- to poor-quality ground water are available from caverns in dolomite and fractures in limestone beds.

Stability of foundations for heavy surface structures is fair on clayey glacial till below the depth of frost penetration. Foundation stability is good to excellent on bedrock of sound dolomite and limestone layers, and good on the massive shale bed. Excavation in clayey glacial till would be easy with power equipment, but walls require support. Dolomite and limestone require drilling and blasting, and because of probably encountering caverns in the dolomite beds drilling time would probably be slow, especially in water-bearing zones. The water table is about 40 to 60 feet from the surface, and lies near the zone of contact of basal glacial till, commonly silty sand or silty clay (Unit 4), and the dolomite and limestone beds. Drainage and sealing of water-bearing zones are necessary, but little or no wall support is needed. Power-equipment operations in the massive shale bed would be mostly easy, but excavation walls would require some support. Drainage, and sealing of any permeable beds of cavernous dolomite, soft sandstone, and sand would also be necessary. Seismic velocities of natural materials surrounding the site mostly range from 1,300 to 4,000 feet per second in the clayey glacial till; 7,000 to 20,000 in the layers of dolomite and limestone; and 3,000 to 14,000 in the massive shale bed, including layers of marl, soft sandstone, and sand; and as much as 20,000 feet per second in layers of dolomite.

Adequate sources for most natural construction materials are present within 2 nautical miles. Dolomite and limestone suitable for most construction uses are available underlying the site, and to the southeast along surface exposures which form short, steep ridges. Abundant quantities of sand and gravel suitable for aggregate and fill are available southwest of the launch site. Fair- to good-quality timber for construction use is readily available adjacent to the site.

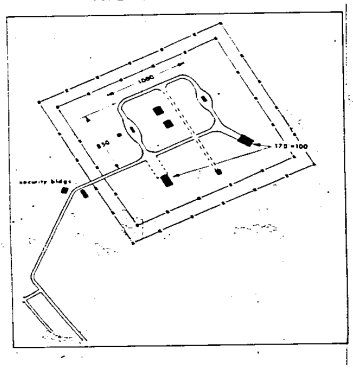
Section III. SUMMARY

The Yedrovo complex is situated on glaciated terrain, with conditions locally well suited for the construction of soft and hard ICBM launch sites. The hills are well suited for the construction of soft sites, but areas with bedrock suitable for the construction of hard sites are located in a narrow, east-west trending zone in the central part of the western half of the mapped area and also in the northwestern part. The only hard site in the complex is located in this zone. Natural construction materials of limestone and dolomite well suited for most construction uses are easily available in abundant quantities. Sand and gravel suitable for aggregate and fill are available from eskers and kames. Good construction timber is readily available. Natural foundation conditions are excellent on exposed bedrock, good on shale, good on kames and eskers, and fair on moraines. Surface and subsurface drainage conditions are mostly good, presenting few construction and maintenance problems.

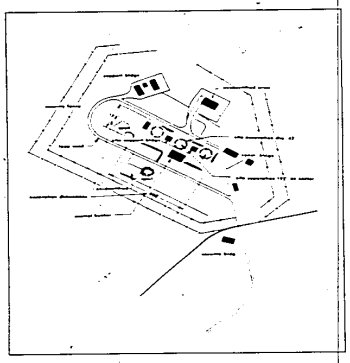
Although the soft sites are randomly scattered, the location of the single hard site may have been selected because of its position on the crest of a minor anticlinal structure composed of hard limestone and dolomite overlying a thick, massive, soft shale bed, with a deep water table.

LAUNCH SITE CONFIGURATIONS

TYPE II (MODULAR) MODE B



TYPE III (ADVANCED INTEGRAL)



NOTE: THE CONFIGURATIONS SHOWN ARE CHARACTERISTIC PATTERNS ONLY, AND ARE NOT NECESSARILY EXACT REPRESENTATIONS OF THE YEDROVO COMPLEX.

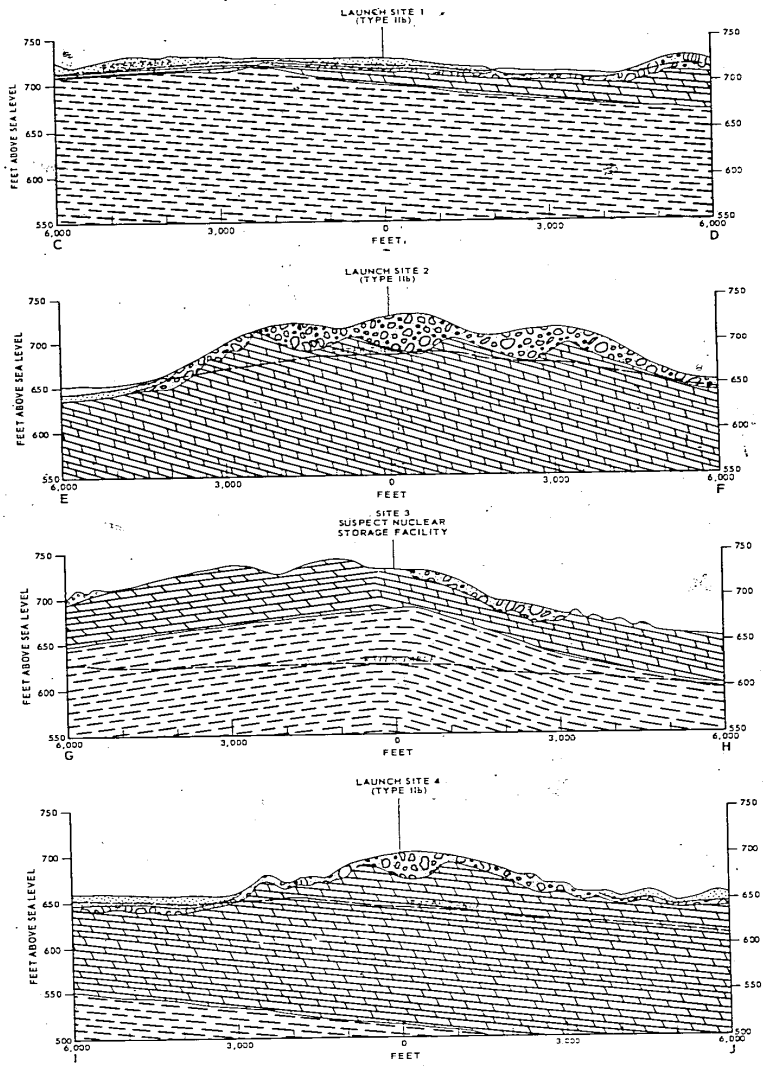
RELIABILITY OF CROSS SECTIONS

THE CROSS SECTIONS ARE BASED ON GEOLOGIC DESCRIPTIONS AND MAPS, DATA ON PHYSIOGRAPHIC FEATURES OF THE SITE AREA, AND TALENT-KEYHOLE PHOTOGRAPHY. ELEVATION AND DEPTH OF LITHOLOGIC UNITS ARE GENERALLY WITHIN ± 50 FEET. RELIABILITY OF SEQUENCE AND COMPOSITION OF INDIVIDUAL LAYERS IS VERY GOOD.

DIAGRAMMATIC GEOLOGIC CROSS SECTIONS AT YEDROVO ICBM LAUNCH SITES

FOR LOCATIONS OF AREAS DIAGRAMMED, SEE MAP ON PAGE 6. FOR EXPLANATION OF GEOLOGIC UNITS, SEE TABLE ON PAGE 7.

HORIZONTAL SCALE 1:20,000
VERTICAL EXAGGERATION 20X



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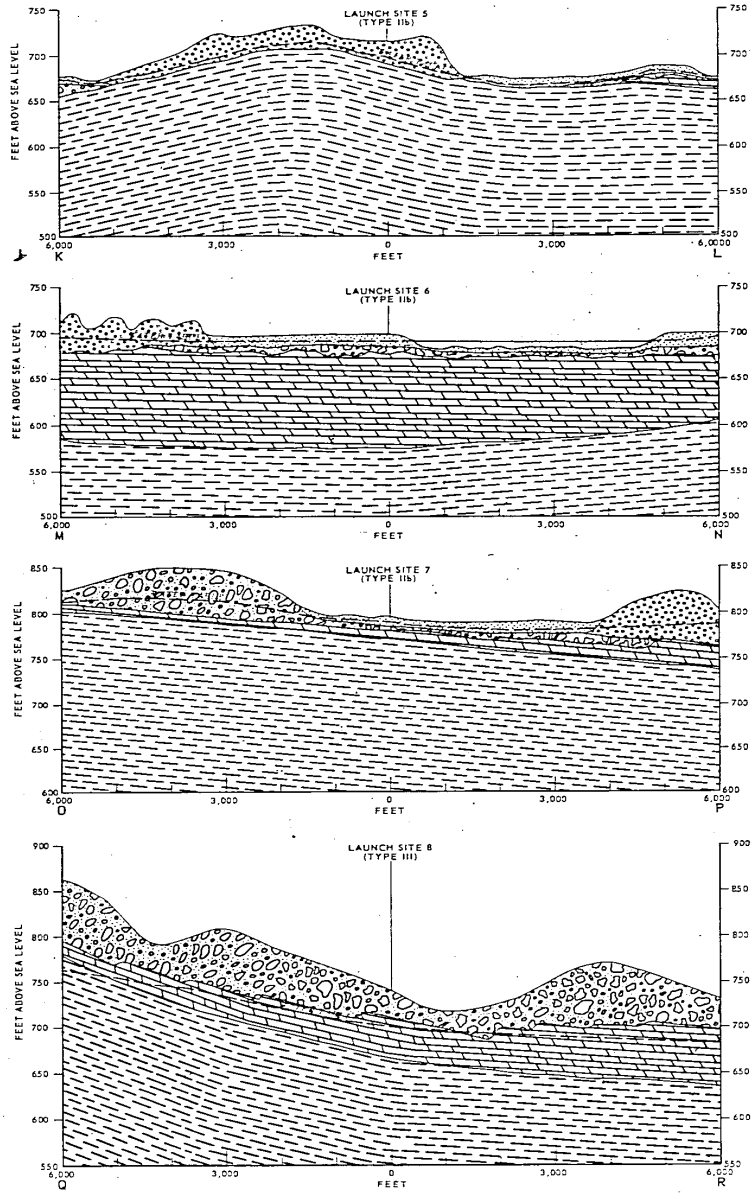
DIAGRAMMATIC GEOLOGIC CROSS SECTIONS
(CONTINUED)



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YEDROVO 5

TOP SECRET

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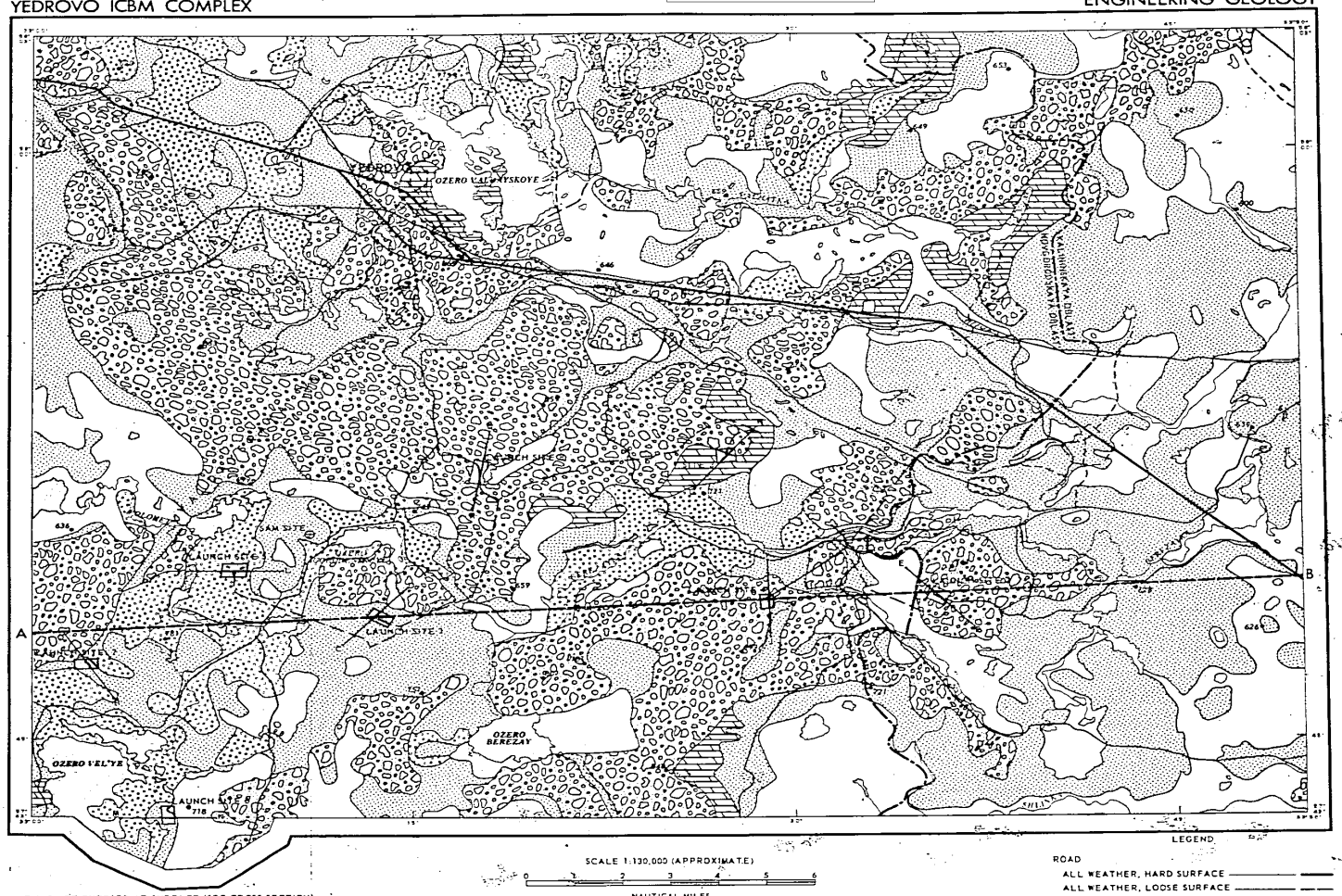
YEDROVO ICBM COMPLEX

ENGINEERING GEOLOGY



LEGEND

SCALE 1:130,000 (APPROXIMATE)

0 1 2 3 4 5 6

NAUTICAL MILES

ROAD
- ALL WEATHER, HARD SURFACE
- ALL WEATHER, LOOSE SURFACE
- FAIR WEATHER, LOOSE SURFACE
- TRACK OR TRAIL

RAILROAD, 5'0" GAGE
- SINGLE TRACK
- DOUBLE TRACK

NARROW GAGE

SECONDARY ADMINISTRATIVE BOUNDARY

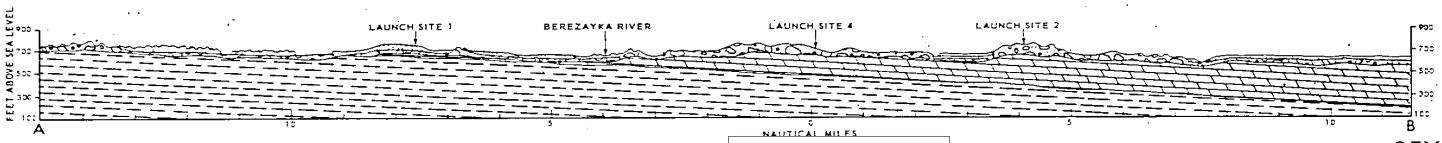
UNIT 6 IS NOT EXPOSED AT SURFACE (SEE CROSS SECTION).

ELEVATIONS IN FEET

ELEVATION DATA FROM ARMY MAP SERVICE 1:250,000 SERIES N501, SHEET NO 36-8.

DIAGRAMMATIC GEOLOGIC CROSS SECTION

VERTICAL EXAGGERATION 15X



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YEDROVO 6

ENGINEERING GEOLOGY								
UNIT	DESCRIPTION (Units arranged in stratigraphic order -- surface to depth of 200 ft. or more)	SUITABILITY FOR CONSTRUCTION			GROUND-WATER SUPPLY*		SEISMIC VELOCITIES (Given for upper unit only; for underlying layers, see seismic velocities of respective units)	
		Foundations	Excavations	Natural Materials	Aquifers	Quantity, Quality, and Siting	Material	Velocity (in feet per second)
1	Peat (Pt)** 1 to 25 ft. thick. Underlain by either silty sandy (Unit 2) or clayey glacial till (Unit 4), 1 to 25 ft. thick. Bedrock, generally less than 50 ft. from surface, either limestone, dolomite, and shale (Unit 5), or shale (Unit 6), extends to depths greater than 430 ft. Numerous depressions and low-lying plains occupied by peat bogs, forest and shrub swamps, and marshes; small lakes usually present.	Soft Sites: Unsuited; water table at or near surface, generally thick peat layers should be removed. Poorly suited to unsuited on underlying weak, saturated, clayey and sandy soils. Bedrock of limestone and dolomite, in places cavernous, and shale fair to good as natural foundation. Depressions flooded from end of April to mid-June and from end of September to early November. Hard Sites: Generally unsuited because of excessive ground water. Fair to good in bedrock with adequate drainage.	Hand tools mostly inadequate in all soils because water table at or near surface; extensive shoring required. Power equipment required in bedrock; limestone and dolomite require drilling and blasting.	Peat unsuited except for insulation. Sand suitable for fine aggregate if washed and screened; fair for fill. Clayey till good for fill. Limestone and dolomite good for building stone, riprap, aggregate, and fill. Shale poor to unsuited for any purpose. Natural materials difficult to develop because of high water table. Construction timber readily available from forest swamps.	Peat and sandy soils extending to depth of 25 ft.; fractured and cavernous zones in limestone and dolomite, usually at depths greater than 50 ft., except in northwest where limestone and dolomite lacking.	In summer, large*** quantities available from peat adjacent to lakes and rivers; meager to small quantities available from smaller peat beds; in winter, meager quantities available. Quality poor because of high bacterial contamination and organic content. Meager to large quantities available from sandy aquifers; quality usually poor because many waters originate from peat beds. Small to large quantities available from limestone and dolomite; quality fair to poor with total dissolved solids in some places exceeding 1,000 p.p.m. (parts per million); bacterial contamination low to high. Below depths of about 800 ft., water brackish to saline. Siting easy but sites subject to flood in spring and fall. Recharge in peat fair in summer, poor in winter; fair in sandy aquifers, good in limestone and dolomite.	Peat	less than 1,000
2	Stratified silty sand (SM), 1 to 25 ft. thick in places, with interbedded, thin layers of clayey sand (SC), sandy silt (ML), and sandy clay (CL) of varied thickness, and overlapping with a thin layer of poorly graded sand and gravelly sand (SP). Peat (Pt) 0 to 3 ft. thick present in scattered depressions. Underlain by clayey glacial till (Unit 4), 0 to 20 ft. thick, but locally as much as 200 ft. thick. Bedrock of either limestone, dolomite, and shale (Unit 5) mostly present in western and southwestern part of mapped area, or shale (Unit 6) mostly present in northwestern part, extends to depths greater than 430 ft. Level to undulating glacial and lacustrine plains with scattered depressions, predominantly forested. Higher-lying parts of plains cultivated.	Soft Sites: Fair on silty sand if compacted and below depth of frost action, about 4 ft.; poor above. Fair on clayey glacial till below depth of frost action, about 2 to 4 ft.; poor above. Unsuited on peat; depressions subject to flood in spring and fall. Water table generally less than 10 ft. from surface. Hard Sites: Fair to good on bedrock; drainage required.	Hand tools mostly inadequate because of high water table; heavy wall support required in saturated soils. Excavation difficult below water table. Power equipment required in bedrock; limestone and dolomite require drilling and blasting, but little or no wall support. Some wall support required in shale.	Silty sand suitable for fine aggregate if washed and screened; fair for fill. Clayey glacial till good for fill. Clayey sand and silty sand fair for fill. Sandy silt poor for fill. Cobbles, boulders, limestone, and dolomite good for building stone, riprap, fill, and aggregate if crushed and screened. Shale poor to unsuited for any purpose. Quarries in bedrock difficult to develop because of high water table. Construction timber readily available.	Sand at contact with clayey glacial till or bedrock at depths of about 10 to 25 ft.; also, silt layers of basal, clayey, glacial till at the contact with bedrock, usually at a depth less than 50 ft. Fractured and cavernous zones in limestone and dolomite at depths usually greater than 50 ft.; limestone and dolomite lacking in northwest.	Small to moderate quantities available from sand; meager to small quantities available from silt. Quality fair to good except near settlements and swamps where highly polluted. Small to large quantities available from limestone and dolomite; quality fair to poor with total dissolved solids in most places exceeding 1,000 p.p.m.; bacterial contamination low to high. Below depths of about 800 ft., water brackish to saline. Siting easy but sites in depressions subject to flood. Recharge mostly fair in sand, poor in silt, and good in limestone and dolomite.*	Sandy soils	700 - 6,300
3	In some places, stratified coarse- to fine-grained sand (SM), with some layers of sandy gravel (GP), 25 to 50 ft. thick, form kames as much as 50 ft. high, usually bordered by depressions of peat bogs, swamps, and marshes. In other places, well-graded sandy gravel (GW) with boulders more than 3 ft. in diameter, 30 to 60 ft. thick, form eskers 75 to 100 ft. or rarely 130 ft. high, usually bordered by plains of mostly silty sand (SM) as much as 25 ft. thick. All underlain by clayey glacial till 0 to 25 ft. thick (Unit 4), and by bedrock of either limestone, dolomite, and shale (Unit 5), or shale (Unit 6), that extends to depths greater than 430 ft. Numerous steep-sided, generally forested, conical and coalesced hills (kames) usually bordered by depressions of peat bogs, swamps and marshes; also numerous, steep-sided, generally grass-covered, narrow, sinuous hills (eskers) bordered by partly cultivated, forested plains.	Soft Sites: Good on sandy gravel below depth of frost action, about 4 ft.; fair above. Good to fair on sand of kames and fair on silty sand of plains if compacted and below depth of frost action, about 4 ft.; poor above. Water table generally within 10 ft. of surface in depressions, 25 ft. in plains. Hard Sites: Fair to good on sands and gravels of kames and eskers; water table generally 15 to 60 ft. from surface; no seepage down to water table except in spring and after heavy rains. Fair to good in bedrock, with adequate drainage.	Easy with hand tools in kames and easy to difficult in eskers because of boulders above water table. Heavy wall support required. Hand tools mostly inadequate in depressions and on plains because of high water table. Power equipment required in bedrock; limestone and dolomite require drilling and blasting.	Sand and silty sand suitable for fine aggregate if washed and screened; fair for fill. Sandy gravel suitable for coarse aggregate if screened; well-graded sandy gravel excellent for fill. Clayey glacial till good for fill. Limestone and dolomite good for building stone, riprap, aggregate, and fill, but quarries difficult to develop because of thick overburden and high water table. Shale poor to unsuited for any purpose. Construction timber readily available.	Sands and gravels at contact with clayey glacial till at depths of 40 to 80 ft. in kames and eskers, within 25 ft. on plains, and within 10 ft. in depressions. Fractured and cavernous zones in limestone and dolomite at depths greater than 50 ft. in depressions and plains, much deeper under kames and eskers; limestone and dolomite lacking in northwest.	Small to moderate quantities available from sands and gravels. Quality fair to good except near settlements and swamps where highly polluted. Small to large quantities available from limestone and dolomite; quality fair to poor with total dissolved solids in most places exceeding 1,000 p.p.m.; bacterial contamination low to high. Below depths of about 800 ft., water brackish to saline. Siting easy but sites in depressions subject to flood. Recharge fair to good in sands and gravels, good in limestone and dolomite.	Kames Eskers, and plains of silty sand	700 - 6,000 1,000 - 6,000
4	Heterogeneous mixture of clay, sand, gravel, cobbles, and boulders (glacial till), classified principally as gravelly clay (CL), and clayey gravel (GC), 25 to 250 ft. thick; a thin layer of silty sand (SM) or silty clay (CL) usually present at base. Peat (Pt), 0 to 3 ft. thick, present in some small, scattered depressions. Underlain by limestone, dolomite, and shale (Unit 5), or shale (Unit 6) that extends to depths greater than 430 ft. Forms ridges and hills (moraines) as much as 250 ft. high; moraines elongated with rounded crests and gentle to steep slopes, generally forested.	Soft Sites: Fair on clayey glacial till below depth of frost action, about 2 to 4 ft.; poor above. Unsuited on peat; depressions subject to flood in spring and fall. Hard Sites: Fair to good in clayey glacial till and bedrock above water table, in places water table at depths of 175 ft.	Hand tools mostly inadequate because of cobbles and boulders; heavy wall support required in saturated soils. Excavation difficult below water table. Power equipment required in bedrock; limestone and dolomite require drilling and blasting but little or no wall support; some support required in shale.	Clayey glacial till good for fill. Clayey sand and silty sand fair for fill. Cobbles, boulders, limestone, and dolomite good for building stone, riprap, fill, and aggregate if crushed and screened. Shale poor to unsuited for any purpose. Quarries in bedrock difficult to develop because of overburden and high water table. Construction timber readily available.	Sands and gravels at or near contact with bedrock at depths of about 25 ft. in depressions, much deeper under moraines. Fractured and cavernous zones in limestone and dolomite at depths usually greater than 50 ft. in depressions, much deeper under moraines; limestone and dolomite lacking in northwest. Aquifers in massive shale at depths of about 175 ft.	Small to moderate quantities available from sands and gravels; quality fair to good except near settlements and swamps where highly polluted. Small to large quantities available from limestone and dolomite; quality fair to poor with total dissolved solids in most places exceeding 1,000 p.p.m.; bacterial contamination low to high. Below depths of about 800 ft., water brackish to saline. Siting easy but sites in depressions subject to flood. Recharge fair to good in sands and gravels, good in limestone and dolomite.	Clayey glacial till	1,000 - 9,000, usually 1,800 - 4,000
5	Thick to thin, alternating, gently inclined beds of limestone, cavernous dolomite, and shale, steeper dipping on flanks of anticlinal structures, present throughout the mapped area except in the northwest. Dolomite exposed in southwestern part, limestone and dolomite exposed in central part, and shale not exposed in mapped area. Thickness of dolomite varies from less than 30 ft. in the southwest to about 80 ft. in the central part. In the east, limestone, cavernous dolomite, and shale, about 290 to 410 ft. thick, overlain by about 5 ft. of peat (Pt), silty sand (Unit 2), and clayey glacial till (Unit 4). Underlain by massive shale (Unit 6) to depth of more than 430 ft. Exposures of cavernous dolomite and limestone form low-lying, steep-sided, inconspicuous ridges with sinkholes present on the generally forested surface.	Soft Sites: Excellent on exposed limestone lacking sinkholes and on dolomite where not cavernous; good on shale. Hard Sites: Good on limestone and dolomite where not fractured or cavernous. Good on underlying massive shale. Ground water encountered at contact zones of limestone and dolomite with shale; drainage difficult in low-lying areas and near lakes, easier in higher-lying areas.	Power equipment and some wall support required in bedrock. Drilling and blasting necessary in limestone and dolomite; walls generally stable. Excavation mostly difficult below water table and in fractured or cavernous rock. Large water seepage may be very difficult to control.	Limestone and dolomite good for building stone, riprap, fill, and aggregate if crushed and screened. Shale poor to unsuited for any purpose. Quarries fairly easy to develop along short, steep slopes of ridges. Construction timber readily available.	Confined to contact of soils with bedrock at the base of ridges and in some sinkholes at depths of less than 10 ft. Aquifers in limestone and dolomite confined to fractured and cavernous zones at depths greater than 10 ft.	Meager quantities of usually fair-quality water seasonally available from base of ridges and sinkholes. Small to large quantities of fair- to poor-quality water perennially available from limestone and dolomite. Total dissolved solids in most places exceed 1,000 p.p.m.; bacterial contamination low to high. Brackish to saline water present from aquifers at depths of about 800 ft. Siting easy. Recharge seasonal in soil aquifers, good in limestone and dolomite.	Limestone, dolomite, and shale	3,000 - 20,000
6	Massive shale bed, 430 to 500 ft. thick, with layers of marl, dolomite, and soft sandstone or sand, gently inclined, dipping to the east. Underlies the entire mapped area.	Soft Sites: Not applicable. Hard Sites: Good in massive shale in central and northwestern part of mapped area where water table about 175 ft. from surface. Elsewhere some drainage required.	Excavation of shale easy with power equipment above water table. Some wall support required.	Shale poorly suited to unsuited for construction purposes. Dolomite good for building stone, fill, and aggregate if crushed and screened. Soft sandstone and sand fair for fill. All rocks except shale available only in limited quantities.	Thin layers of cavernous dolomite, sandstone, and sand within 500 ft. of surface in the western part of the mapped area to about 200 ft. in the eastern part.	Meager quantities available. Quality fair to poor with total dissolved solids exceeding 1,000 p.p.m.; bacterial contamination probably low. At depths generally below 800 ft., water brackish to saline, unpotable. Siting easy. Recharge slow.	Soft shale Marl Dolomite Sandstone	3,000 - 14,000 6,000 - 11,000 up to 20,000 mostly 3,000 - 6,000

*SURFACE WATER SUMMARY: Large quantities of good- to fair-quality water are perennially available from numerous deep (20 to more than 130 ft.) lakes in the mapped area. Numerous potential water-supply points, easy to develop with short intakes, are present along well-defined, firm shores of large lakes. Large to small quantities of poor-quality water, with high bacterial contamination, are perennially available from numerous small, sluggish streams, small, shallow lakes less than 20 ft. deep, marshes, and swamps. Potential water-supply points are difficult to develop and maintain because long intakes are required to cross marshes or swamps bordering small lakes and streams, and because poorly defined shorelines of small lakes and stream channels are subject to seasonal change. Lake levels at maximum height in mid-May, remain constant till early June, then lower by 3 ft. in mid-July. They rise slightly in fall, and lower in winter to their lowest level, about 3 ft. below May level. The lakes are frozen from mid-November to the end of April.

**The nomenclature and accompanying soil symbols used in this table are in accordance with those defined and described in the Unified Soil Classification System, Corps of Engineers, U.S. Army T.M. No. 3-357, Waterways Experiment Station, Vicksburg, Mississippi, March 1953.

***Large: more than 1,500,000 g.p.d. (gallons per day); moderate: 150,000 to 1,500,000 g.p.d.; small: 15,000 to 150,000 g.p.d.; meager: less than 15,000 g.p.d. Quantities based on assumed multiple well development.

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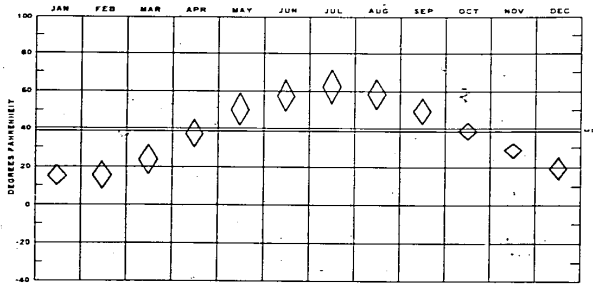
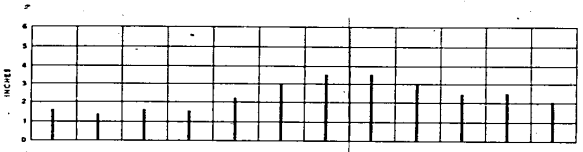
CLIMATE



MONTHLY TEMPERATURES

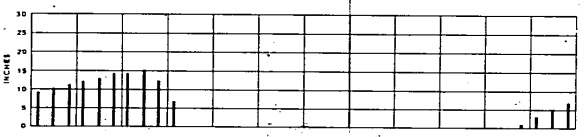
MEAN DAILY MAXIMUM
MEAN TEMPERATURE
MEAN DAILY MINIMUM
ABSOLUTE MAXIMUM 93° F
ABSOLUTE MINIMUM -48° F

MEAN ANNUAL TEMPERATURE 38° F



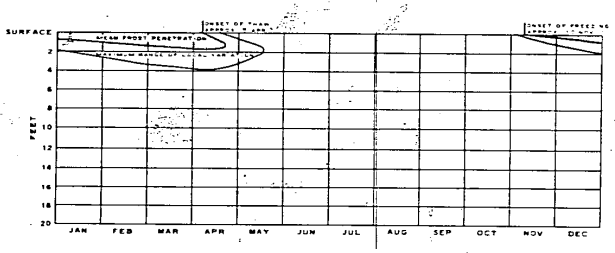
MEAN MONTHLY PRECIPITATION

MEAN ANNUAL PRECIPITATION 28 2 INCHES



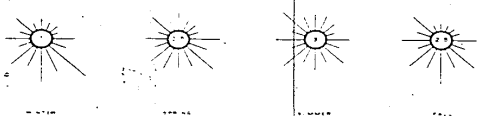
MEAN SNOW DEPTHS

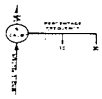
(BY 10-DAY PERIODS)



FROST DEPTHS

SURFACE WIND DIRECTIONS





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YEDROVO 8

SECRET

TOP SECRET [redacted] 25X1

DEFENSE INTELLIGENCE AGENCY
WASHINGTON, D. C. 20301

SAO/PC 270/1-1-64 7 August 1964

SUBJECT: Addendum No. 2 to SAO/PC 270/1-1-64

TO: Recipients of Publication Cited

SAO/PC 270/1-1-64, ANALYSES OF THE PHYSICAL ENVIRONMENT AT SOVIET ICBM COMPLEXES, is amended as follows:

This engineering-geology study is an addendum containing data on new launch sites discovered at the Yedrovo complex after research on the original study was completed. Addenda for new launch sites at other complexes, also designed to be inserted with SAO/PC 270/1-1-64, will be issued to update the earlier, more comprehensive report.

FOR THE DIRECTOR: [redacted] 25X1

ELMORE G. LAWTON
Colonel USA
Chief, Environment Division

YEDROVO ICBM COMPLEX

Two new launch sites have been constructed at the Yedrovo ICBM complex; one is a soft site located near an earlier site now identified as a launch support facility, and the other is a hard site that replaces an earlier soft site. Both of these new sites have generally good foundation materials with low to moderate seismic velocities.

LAUNCH SITE 7

Launch Site 7, a Type IId soft site, is located 0.3 nautical mile west-northwest of a launch support facility (previously identified as Site 7) on the side of a morainal hill of clayey glacial till. Relief within 1 nautical mile is about 70 feet. Vegetation is primarily dense forest except for cultivated areas to the south. Tree types are mostly spruce and birch up to 60 feet high and 18 inches in diameter, intermixed with pine and aspen also 60 feet high and up to 12 inches in diameter.

The environmental factors at Site 7 are similar to those at Launch Site 8 except that clayey glacial till (Unit 4) is 40 to 50 feet thick, the bedrock of cavernous dolomite (Unit 5) is 10 to 20 feet thick, and depth to ground water is about 25 to 30 feet. Mostly small quantities of fair- to good-quality ground water are available from caverns in dolomite and fractures in limestone beds at depths between 45 and 55 feet. Natural construction materials are available within 3.5 nautical miles of the launch site. Bedrock of limestone and dolomite, suitable for most construction uses, is available to the south along surface exposures which form short, steep ridges. Abundant quantities of sand and gravel suitable for aggregate and fill are available from eskers, also located south of the site. Fair- to good-quality timber is readily available adjacent to the launch site.

LAUNCH SITE 9

Launch Site 9, a Type III hard site 16.5 nautical miles west-southwest of Yedrovo, is located adjacent to Launch Site 5 which has apparently been abandoned. Depth to the water table and to shale bedrock (Unit 6) is about 35 feet; excavation below the water table encounters no difficulties, and the shale is well suited for silo construction. Other engineering-geology conditions described at Launch Site 5 are also applicable to Site 9.

[redacted] 25X1

GROUP 1
EXCLUDED FROM AUTOMATIC DOWNGRADING AND DECLASSIFICATION

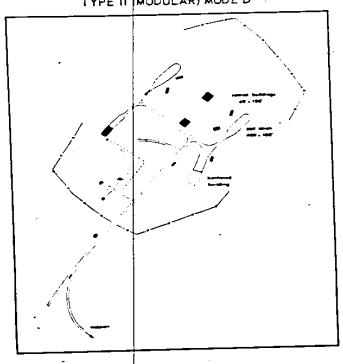
TOP SECRET [redacted] 25X1

TOP SECRET

25X1

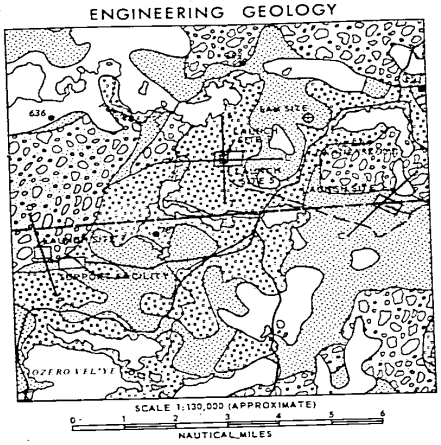
YEDROVO ICBM LAUNCH SITES 7 AND 9

TYPE II (MODULAR) MODE D



NOTE: THE CONFIGURATION SHOWN IS A CHARACTERISTIC PATTERN ONLY, AND IS NOT NECESSARILY AN EXACT REPRESENTATION OF THE YEDROVO COMPLEX.

ENGINEERING GEOLOGY



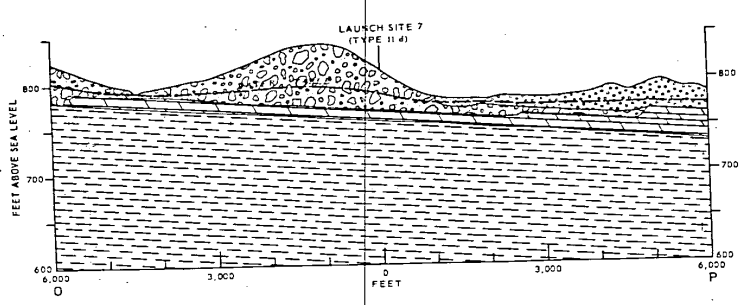
FOR EXPLANATION OF GEOLOGIC UNITS, SEE TABLE ON PAGE 7

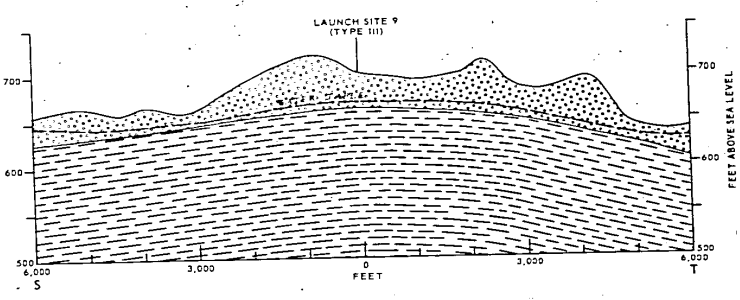
DIAGRAMMATIC GEOLOGIC CROSS SECTIONS

HORIZONTAL SCALE 1:20,000

VERTICAL EXAGGERATION 20X

RELIABILITY: SEE PAGE 4





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DEPARTMENT OF DEFENSE
WASHINGTON, D. C., 20301

SAO/PC 270/1-1-64

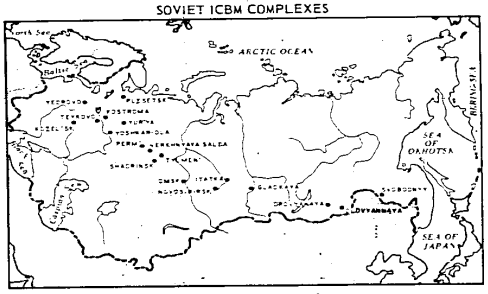
(Supersedes Special Engineer Intelligence Report No. 2 and addenda)

ANALYSIS OF THE PHYSICAL ENVIRONMENT AT YOSHKAR-OLA ICBM COMPLEX

THIS STUDY IS ONE OF A SERIES OF ALL-SOURCE INTELLIGENCE REPORTS ON ICBM COMPLEXES IN THE U.S.S.R. ADDITIONS WILL BE PUBLISHED AT INTERVALS AS INFORMATION BECOMES AVAILABLE.

This study is based on information available as of July 1963.

SOVIET ICBM COMPLEXES



PREPARED BY
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D/ESPA, ARMY MAP SERVICE, C of E

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ANALYSIS OF THE PHYSICAL ENVIRONMENT AT THE YOSHKAR-OLA ICEM COMPLEX

Section I. INTRODUCTION

The physical environment in the vicinity of the Yoshkar-Ola ICEM complex has been analyzed and the engineering-geology conditions at each launch site are presented. The purpose of this study and similar studies of other complexes is to provide data that can be used to determine the criteria used by the Soviets in selecting locations for their ICEM sites and to evaluate how terrain conditions probably influenced construction of the complex and will influence its physical vulnerability. Knowledge of Soviet terrain requirements for ICEM sites may aid in locating additional sites in a complex and in finding new complexes.

The Yoshkar-Ola complex at the time of study consisted of six Type II soft sites and the necessary support facilities. The complex is approximately 10 nautical miles east-southeast of Yoshkar-Ola and 30 nautical miles north of the Volga River. It is constructed on the eastern upland margin of the Volga River valley in central European Russia. Terrain in the vicinity of the complex consists of a gently rolling upland that is deeply dissected by streams and is cultivated in its higher, better drained portions but densely forested elsewhere. Adjoining the upland on the west is a nearly flat, gently sloping plain which is densely forested and has numerous swamps and marshes. The area has a dry, continental climate characterized by warm summers and cold winters; it lies far south of the zone of continuous permafrost but has average seasonal frost penetration of about 2 feet, with a maximum depth of about 6 feet. Snowfall is moderately heavy and persists from early November through mid-April. Earthquakes have not been reported in the area.

Section II. ENGINEERING GEOLOGY

Analysis of the physical environment at the Yoshkar-Ola ICEM complex is based on a study of Soviet publications in the fields of geology and soils, modified by interpretation of TALENT-KEYHOLE photography. Detailed information is presented in the accompanying table and graphics.

Components of the Yoshkar-Ola complex are situated on densely forested parts of a broad, gently rolling upland dissected by numerous streams, ravines, and gullies. The upland is formed of soft, massive shale (Unit 5), mostly 300 to 400 feet thick, and gently to moderately inclined to the west; it includes numerous thin layers of soft sandstone and some layers of limestone and marl. The massive bed of shale underlies all but the southeast corner of the mapped area, and in turn is underlain by beds of dense, hard limestone and dolomite (Unit 6), which are also gently to moderately inclined to the west and are exposed in the southeast portion of the mapped area. Overlying the massive shale bed is a layer of weathered shale that is 6 to as much as 30 feet thick and consists of silty and sandy clay, silt and clayey silt, and silty sand; however, soil is commonly absent in the ravines.

West of the upland lies a nearly flat, gently inclined, densely forested plain formed of glacial-lacustrine soils (Unit 4); the upper 16 to 25 feet of soil on the plain is mostly clay, and silty and sandy clay with some layers and lenses of sand; the clayey soils overlie mostly stratified sand which has some lenses of gravel, is 150 to 260 feet thick, and extends to bedrock. Flood plains of the larger streams are principally alluvium -- sand with some silt and clay mixtures (Unit 3), 20 to 30 feet thick, in places overlain by peat, sand, and gravel, usually less than 3 feet thick. Dunes of windblown sand (Unit 2), about 20 to 25 feet high, 100 feet wide, and mostly 1,500 feet long, are present in the southern part of the mapped area. Peat (Unit 1), 2 to 20 feet thick but mostly 6 to 10 feet thick, is present in the numerous marshes and swamps of the plains area.

Natural construction material of hard limestone and dolomite well suited for construction purposes is easily available in quantity along steep valley walls in the southeast corner of the mapped area. Large quantities of sand suitable for fine aggregate and limited amounts of gravel suitable for coarse aggregate are easily available along streams. Abundant quantities of sand and some gravel also are available by dredging operations in the thick glacial-lacustrine deposits, and large quantities of sand suitable for fine aggregate are available from the dunes. Most natural materials, excluding peat, are suitable for fill. Good construction timber is readily obtainable from the widespread dense forests.

In general, the upland can be considered well suited for construction of missile sites, the plain moderately to poorly suited. Natural foundations for surface structures in northern and eastern parts of the mapped area are fair on shale and soft sandstone, good on sound limestone layers, but only fair to poor where limestone is cavernous and fractures and joints are numerous; marl layers are only fair to poor. Natural foundations on bedrock in the southeast corner of the mapped area are excellent on dolomite and on sound, hard limestone, but fair to poor where limestone is cavernous and joints and fractures are numerous. Clayey and silty soils are poor in frost-susceptible zones to depths of about 4 feet, fair to poor on clayey soils, and poor on silty soils below 4 feet. Sandy soils are poor to fair to depths of frost penetration, about 5 to 6 feet, and good to fair below. Valley bottoms are poorly suited for natural foundations, as they are subject to flooding; swamps and marshes are unsuited because of unstable peat deposits and poor drainage.

Excavation of unconsolidated material and bedrock is easy with power equipment except in limestone and dolomite, which require drilling and blasting. Excavation walls need strong support in unconsolidated material and some support in bedrock except limestone and dolomite, where walls require little or no support unless strongly fractured. Some drainage or grouting is necessary to control seepage at the contact of soils with bedrock. Much grouting is necessary to waterproof excavations where artesian water-bearing layers of sand, gravel, and soft sandstone, and joints and fractures in limestone, marl, and dolomite are encountered. Surface drainage of the upland is good because of slope gradients, but subsurface drainage is poor in clayey soils and shale, fair in silt layers, and good in sand and gravel layers, soft sandstone, and joints and fractures in limestone, marl, and dolomite. Seismic velocities range from [illegible] to 1,100 feet per second in peat, are mostly 1,500 to 4,000 feet per second in sand, clay, and silt of alluvial and glacial-lacustrine deposits; mostly 3,000 to 13,000 feet per second in shale with sandstone, limestone, and marl layers, and mostly 14,000 to 20,000 feet per second in hard, dense limestone and dolomite.

<u>Large</u>* quantities of fair- to poor-quality surface water are perennially available from the Malaya Kokshaga and Yushut Rivers. Variable quantities of mostly poor-quality surface water are available from tributary streams, small lakes, and swamps and marshes which may become dry in summer and usually freeze solid in winter. Surface-water sources are usually high in bacterial contamination, especially in summer. Mostly <u>large</u> to <u>moderate</u> quantities of ground water are available from sand and gravel layers, usually at depths of 20 to 150 feet, and from fractures and joints in limestone and from soft sandstone layers at greater depths. Quality is good to fair, usually with low bacterial contamination; water from depths greater than 300 to 500 feet is mostly brackish to saline.

LAUNCH SITE 1

Launch Site 1, a Type IIb soft site, is located on a slight rise of a gently rolling upland; it is about 9.5 nautical miles east-southeast of Yoshkar-Ola. Relief within 1 nautical mile is about 30 feet. Vegetation is dense evergreen forest except to the west and northeast, where strips have been logged. Trees are predominantly Scotch pine up to 70 feet tall and 18 inches in diameter, and Siberian spruce up to 60 feet tall and 12 inches in diameter. The trees provide good construction timber.

The site is on a bed of soft, massive shale (Unit 5), about 300 feet thick, with numerous thin layers of soft sandstone and some layers of limestone and marl; the shale dips moderately to the west and is overlain by 6 to about 10 feet of silty and sandy clay (CL), silt and clayey silt (ML), and silty sand (SM). Natural foundations are poor on clayey and silty soils to depths of about 4 feet because these materials are subject to frost action, below the frost zone, conditions for foundations are fair to poor on clayey soils and poor on silty soils. Foundations are poor to fair on sandy soils within the frost zone, about 5 to 6 feet, and good to fair below the depth of frost action. Foundations on bedrock are fair on shale and soft sandstone; good on sound limestone, but only fair to poor where limestone is cavernous, and fractures and joints are numerous, and fair to poor on marl. Surface drainage is good, but subsurface drainage is poor in shale and in overlying predominantly clayey soils, which are of low permeability. The water table is at the contact of soils with bedrock, generally at depths of about 6 to 10 feet.

Excavation of shale, soft sandstone, marl, and overlying soils is easy with power equipment, but beds of limestone require drilling and blasting. Walls in soils require gentle slopes or strong support to prevent slumping, in bedrock, some support is needed in all material except limestone, which needs little or no support. Some drainage provision or grouting is necessary to control seepage at the contact of soils with bedrock. Seismic velocities range mostly between 3,000 and 13,000 feet per second in shale with thin layers of soft sandstone, limestone, and marl, and mostly between 1,500 and 4,000 feet per second in the overlying predominantly clayey soils.

<u>Large</u> quantities of surface water are perennially available from the Malaya Kokshaga River, about 7 nautical miles west, and <u>large</u> to <u>meager</u> quantities are seasonally available from small streams within 6 nautical miles of the site. Quality of the surface water is fair to poor, and it is usually high in bacterial contamination. Mostly <u>moderate</u> to <u>large</u> quantities of good- to fair-quality ground water, usually with low bacterial contamination, are available from soft sandstone layers and from joints and fractures in limestone and marl beds at depths of about 100 feet. At depths greater than about 300 feet, ground water increases in salinity and becomes impotable.

Limestone (Unit 5) in the vicinity of the site is well suited for most construction purposes, including crushed rock for aggregate, but it is limited in availability; however, large quantities of hard limestone and dolomite (Unit 6), suitable for most construction purposes, are available from surface exposures along steep valley walls within 25 nautical miles to the southeast. Soft sandstone and silty sand soil available locally are suitable for fill, and, if screened, for fine aggregate. Silty and clayey soils, and shale and marl are suitable for fill if frost susceptibility is not a factor. Abundant amounts of sand suitable for fine aggregate and limited quantities of gravel suitable for coarse aggregate are easily available from flood plains and valley bottoms (Unit 3); large quantities of sand and limited amounts of gravel are available with some difficulty from pits excavated in the thick glacial-lacustrine deposits (Unit 4) 10 to 20 nautical miles from the site. Sand suitable for fine aggregate is available in quantity from sand dunes (Unit 2) about 12 nautical miles south of the site. Good construction timber is readily available from adjacent dense forests.

LAUNCH SITE 2

Launch Site 2, also of Type IIb configuration, is about 14.5 nautical miles east-southeast of Yoshkar-Ola and is situated on a gently rolling upland surface near a gently sloping tributary stream valley. Relief within 1 nautical mile is about 80 feet. Vegetation is dense evergreen forest similar to that at Launch Site 1, but with patches of cutover forest in various stages of regrowth. Other environmental aspects at Site 2 are similar to those at Site 1.

LAUNCH SITE 3

Launch Site 3, a Type IIc soft site, is about 17 nautical miles east-southeast of Yoshkar-Ola on a gently rolling upland surface near the eastern margin of the Malyy Kundysh valley. Relief within 1 nautical mile is about 120 feet. All environmental aspects are similar to those at Site 1.

LAUNCH SITE 4

Launch Site 4, another Type IIb soft site, is situated on a nearly flat upland surface about 20 nautical miles east-southeast of Yoshkar-Ola. Relief within 1 nautical mile is about 20 feet. Vegetation is dense evergreen forest similar to that at Launch Site 1 but with numerous cutover strips in various stages of regrowth. Other environmental aspects at Site 4 are similar to those at Site 1.

LAUNCH SITE 5

Launch Site 5, a Type IIc soft site, is situated on a nearly flat upland surface about 12 nautical miles east-southeast of Yoshkar-Ola. Relief within 1 nautical mile is only about 20 feet. All environmental aspects are similar to those at Site 1.

LAUNCH SITE 6

Launch Site 6, also of Type IIc configuration, is situated on a gently rolling upland surface adjacent to the eastern bank of the upper course of the incised Malyy Kundysh River. This site is located about 19.5 nautical miles east of Yoshkar-Ola in an area where relief within 1 nautical mile is about 100 feet. All environmental aspects are similar to those at Site 1.

Section III. SUMMARY

The Yoshkar-Ola ICEM complex is on a nearly flat to gently rolling upland surface that is free of permafrost and where earthquake activity has not been reported. Vegetation is dense evergreen forest which provides good ground and some air concealment of construction activities. The selected terrain is well suited for the construction of soft launch sites and, on the basis of geologic conditions, would be favorable for the construction of hard (silo-type) sites. All six of the deployed sites rest on an easily drained upland surface underlain by 6 to about 10 feet of predominantly clayey soils which grade down to a soft, massive shale bed, with numerous layers of soft sandstone and some limestone and marl. The clayey soils provide poor natural foundations within the zone of frost penetration, about 4 feet, and fair to poor natural foundations below the frost zone. Foundations on the gently to moderately west-dipping rock beds are fair on shale, soft sandstone, and marl, and good on compact limestone. Excavation of soils, shale, soft sandstone, and marl is easy with power equipment but walls require support. Limestone requires drilling and blasting, but walls stand with little or no support. Drainage provisions are necessary at the seepage zone present at the contact of soils with bedrock. Grouting is necessary in deep excavations that intersect water-bearing, soft sandstone layers and fractures and joints in limestone and marl. Dense, hard limestone and dolomite are well suited natural construction materials for most uses and are easily available along steep valley walls about 25 nautical miles to the southeast. Layers of limestone within the soft, massive shale bed provide limited quantities of suitable hard rock. Large quantities of sand and gravel suitable for fine and coarse aggregate are available from plains and stream valleys adjacent to the uplands. Good construction timber is readily available from the dense forests, and abundant perennial water supplies are obtainable from shallow to moderately deep ground-water sources and from the Malaya Kokshaga and Yushut Rivers. The prevailing wind direction is to the northeast, away from populated areas.

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* For explanation of water terms, see Engineering Geology table footnote ***

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YOSHKAR-OLA

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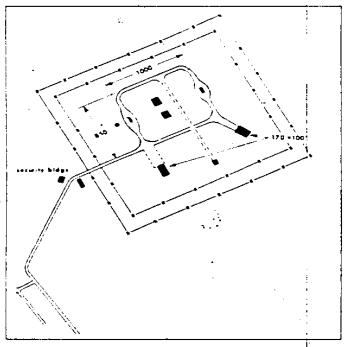
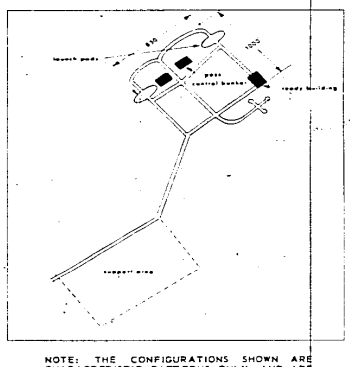
LAUNCH SITE CONFIGURATIONS

TYPE II (MODULAR) MODE B



TYPE II (MODULAR) MODE C



NOTE: THE CONFIGURATIONS SHOWN ARE CHARACTERISTIC PATTERNS ONLY, AND ARE NOT NECESSARY EXACT REPRESENTATIONS OF THE YOSHKAR-OLA COMPLEX.

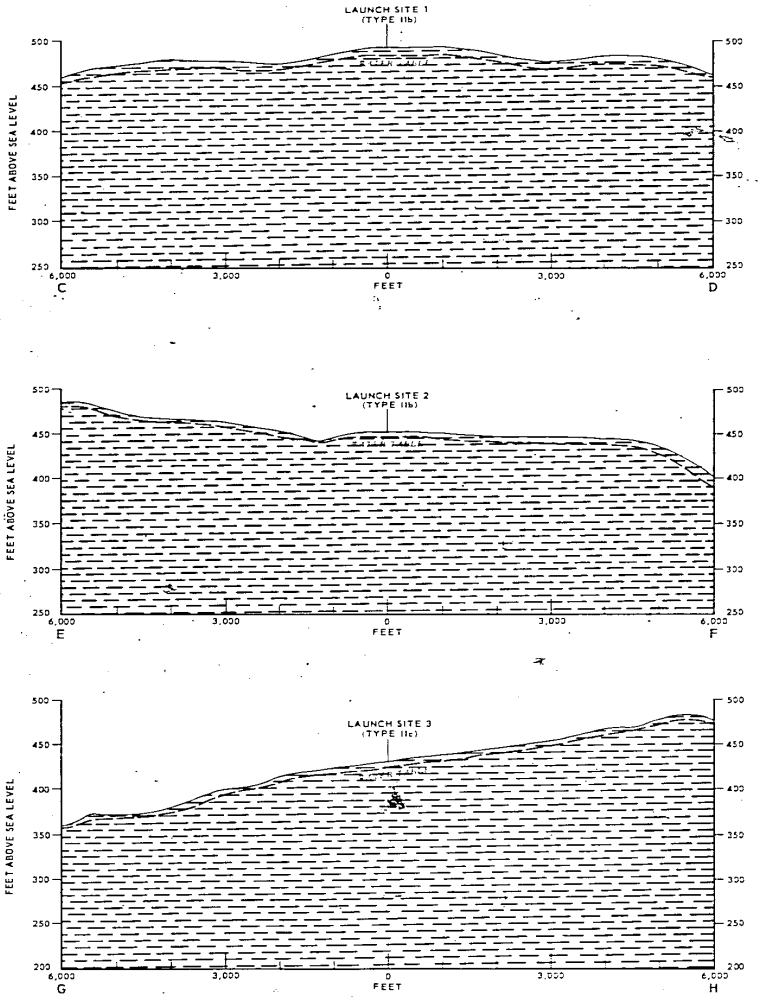
RELIABILITY OF CROSS SECTIONS

DATA ON SEQUENCE, THICKNESS, AND COMPOSITION OF LAYERS ARE BASED ON GEOLOGIC LITERATURE AND INFORMATION REGARDING PHYSIOGRAPHIC FEATURES OF THE GENERAL AREA OF THE SITES, MODIFIED GREATLY BY TALENT-KEYHOLE PHOTOGRAPHY. RELIABILITY OF INFORMATION ON SEQUENCE AND COMPOSITION OF SOIL LAYERS AND ROCK FORMATIONS IS GOOD, BUT INFORMATION ON SEQUENCE AND THICKNESS OF INDIVIDUAL ROCK LAYERS IS POOR. RELIABILITY OF ELEVATIONS IS ± 40 FEET.

DIAGRAMMATIC GEOLOGIC CROSS SECTIONS AT YOSHKAR-OLA ICBM LAUNCH SITES

FOR LOCATIONS OF APEAS AS DIAGRAMMED, SEE MAP ON PAGE 5; FOR EXPLANATION OF GEOLOGIC UNITS, SEE TABLE ON PAGE 7.

HORIZONTAL SCALE 1:20,000
VERTICAL EXAGGERATION 20X



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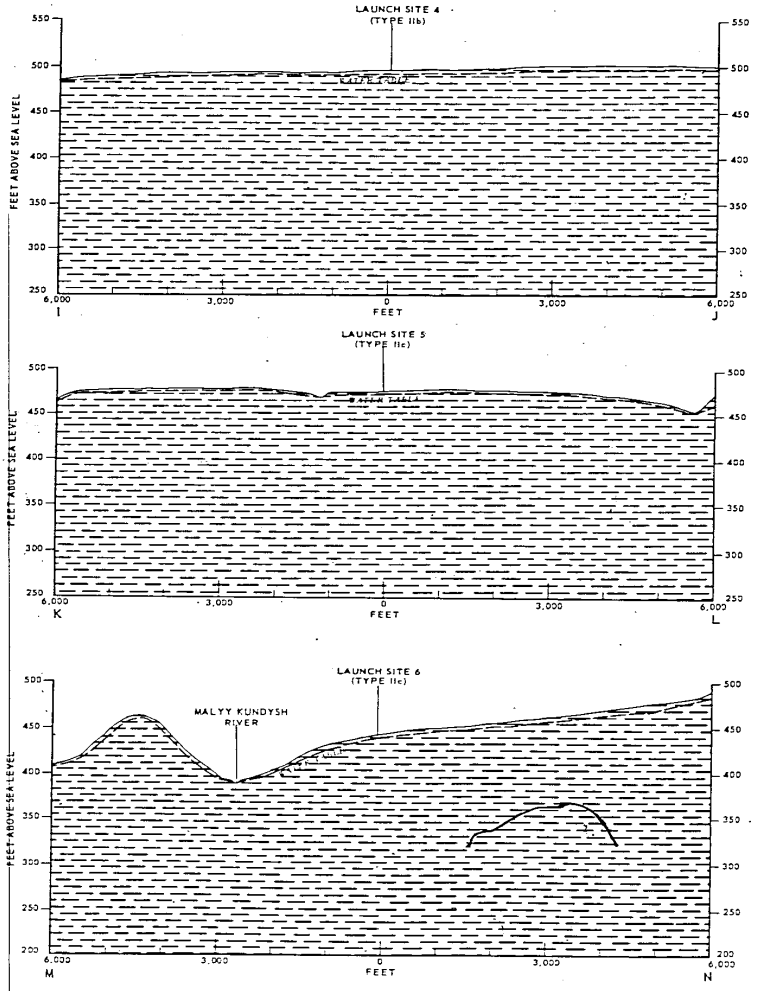
DIAGRAMMATIC GEOLOGIC CROSS SECTIONS
(CONTINUED)



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YOSHKAR-OLA 5

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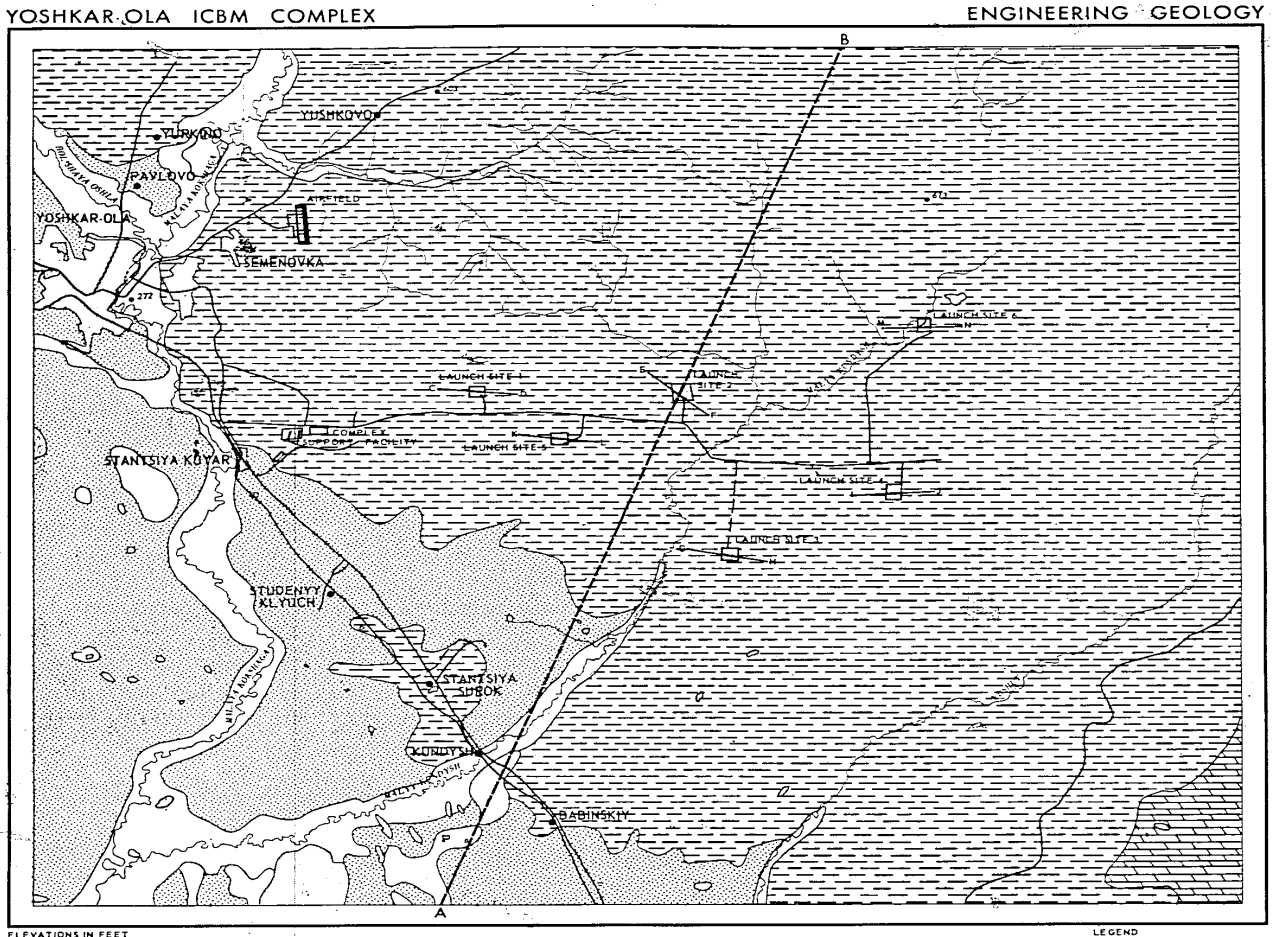
YOSHKAR-OLA ICBM COMPLEX

ENGINEERING GEOLOGY

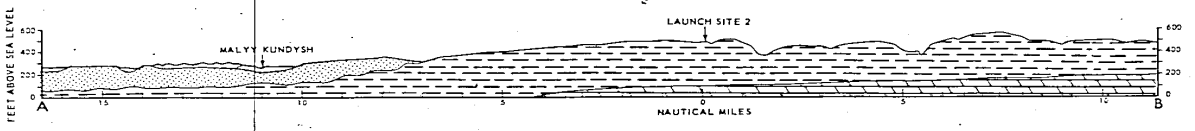


ELEVATIONS IN FEET
ELEVATION DATA FROM ARMY MAP SERVICE
1:250,000 SERIES N501, SHEETS NO 39-10 AND NO 38-12

SCALE 1:165,000 (APPROXIMATE)
0 1 2 3 4 5 6
NAUTICAL MILES

LEGEND
ROAD
ALL WEATHER, LOOSE SURFACE
FAIR WEATHER, LOOSE SURFACE
RAILROAD, 5'0" GAGE
RAILROAD, NARROW GAGE

DIAGRAMMATIC GEOLOGIC CROSS SECTION
VERTICAL EXAGGERATION 20X



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YOSHKAR-OLA 6

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ENGINEERING GEOLOGY

UNIT	DESCRIPTION (Units arranged in stratigraphic order; surface to depth of 200 ft, or more)	SUITABILITY FOR CONSTRUCTION			GROUND-WATER SUPPLY		SEISMIC VELOCITIES (Given for upper layer only for overlying layers, see section; velocities of respective units)	
		Foundations	Excavations	Natural Materials	Aquifers	Quantity, Quality, and Siting	Material	Velocity (in feet per second)
1	Peat (Qrm), 2 to 20 ft. thick but commonly 4 to 10 ft. thick. Channel fill or alluvial sands (Qal) 15 to 30 ft. thick, along the Lyons Landings and Maine Sunrise River valleys, and in glacial-lacustrine units (Qgl) in Lyons Landings and Maine Sunrise River valleys and Bald Knob, with some gravels, to depths of 100 ft. Bedrock: Pottsville sandstone of Mifflin Formation (Pmf) and Lower Kittanning and Mahaffey Members of Allegheny Formation (Pal), 200 ft. thick, underlies all of area. Limestone and marl (Qml) 5 to 20 ft. thick, underlies Lyons Landings and Maine Sunrise River valleys. Limestone and dolomite (Qcd) 40, 220 ft. thick, underlies Bald Knob. Lyons, reworked, alongwall silt of windblown sand plastered to glacial tills and bluffs.	Bearing Value: Unconsolidated materials: Poor to fair. Bedrock: Fair to good in sandstone and limestone. Settlement: Unconsolidated materials: Poor to fair, compressible and subsidence. Drainage: Very difficult. Fair to good as bedrock.	Unconsolidated materials: Poor to fair, compressible, subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Unconsolidated materials: Poor to fair, compressible, subsidence. Bedrock: Fair to good in sandstone and limestone.	Peat, varies in depths of about 2 to 15 ft. Channel fill, alluvial sands (Qal) 15 to 30 ft. thick, and glacial-lacustrine units (Qgl) 100 ft. thick, are sources of water in Lyons Landings and Maine Sunrise River valleys. Bedrock: Pottsville sandstone of Mifflin Formation (Pmf) and Lower Kittanning and Mahaffey Members of Allegheny Formation (Pal), 200 ft. thick, underlies all of area. Limestone and marl (Qml) 5 to 20 ft. thick, underlies Lyons Landings and Maine Sunrise River valleys. Limestone and dolomite (Qcd) 40, 220 ft. thick, underlies Bald Knob.	Unconsolidated materials: Poor to fair, compressible, subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Peat	700 - 1,100
2	Sand (Qf) in dunes about 20 to 25 ft. high, 100 ft. wide, and about 1,500 ft. long, trended northeast. Lyons Landings and Maine Sunrise River valleys, and Bald Knob. Lyons Landings and Maine Sunrise River valleys, and Bald Knob. Lyons, reworked, alongwall silt of windblown sand plastered to glacial tills and bluffs.	Bearing Value: Good to fair, as well-drained dune sand. Settlement: Good to poor, as well-drained dune sand. Drainage: Good to poor. Slope Stability: Good to poor. Fair to good in unconsolidated. Poor to fair.	Sand with boundaries, mainly compaction sliding, support to proposed alignment.	Dune sand, good site alternate and specific locations, good to poor, as well-drained dune sand. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Dune sand water bearing at contact with underlying materials. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Subsurface exploration should be carried out to determine depth to water table. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Dune sand	1,000 - 1,900 where dry 1,900 - 2,000 where wet
3	Alluvial sands (reworked sand (Qal), clayey sand (Qcl), silty sand (Qsl), and silty clay (Qsc)) and glacial-lacustrine sands (Qgl) and clays (Qgc) in Lyons Landings and Maine Sunrise River valleys, and Bald Knob. Alluvial sands (Qal) 15 to 30 ft. thick, underlies all of area. Glacial-lacustrine sands (Qgl) and clays (Qgc) 100 ft. thick, underlies Lyons Landings and Maine Sunrise River valleys. Bedrock: Pottsville sandstone of Mifflin Formation (Pmf) and Lower Kittanning and Mahaffey Members of Allegheny Formation (Pal), 200 ft. thick, underlies all of area. Limestone and marl (Qml) 5 to 20 ft. thick, underlies Lyons Landings and Maine Sunrise River valleys. Limestone and dolomite (Qcd) 40, 220 ft. thick, underlies Bald Knob. Alluvial plains of the Maine Sunrise River and its tributaries, consisting of sand, silt, and clay, plastered to glacial tills and bluffs. Lyons, reworked, alongwall silt of windblown sand plastered to glacial tills and bluffs.	Bearing Value: Good on gravels. Poor to fair on sands and silts. Settlement: Good on gravels. Poor to fair on sands and silts. Drainage: Good on gravels. Poor to fair on sands and silts. Slope Stability: Good on gravels. Poor to fair on sands and silts.	Sand on gravel, and fine sand and silt with boundaries, mainly compaction sliding, support to proposed alignment. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Sand on gravel, and fine sand and silt with boundaries, mainly compaction sliding, support to proposed alignment. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Lenses and layers of fine sand and gravel in clay and silt. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Subsurface exploration should be carried out to determine depth to water table. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Peat Sand and clay Silt Gravel	700 - 1,100 1,000 - 6,500 1,000 - 1,500 - 4,000 1,000 - 4,200 1,500 - 1,000
4	Glacial-lacustrine sands, generally about 150 ft. thick, though sands within them may be about 200 ft. thick, underlie about 25 sq. mi. in the Lyons Landings and Maine Sunrise River valleys. Sands (Qgl) and sandy clays (Qgc) and clay (Qgc) underlie about 25 sq. mi. in the Lyons Landings and Maine Sunrise River valleys. Alluvial sands (Qal) underlie about 15 sq. mi. in the Lyons Landings and Maine Sunrise River valleys. Bedrock: Pottsville sandstone of Mifflin Formation (Pmf) and Lower Kittanning and Mahaffey Members of Allegheny Formation (Pal), 200 ft. thick, underlies all of area. Limestone and marl (Qml) 5 to 20 ft. thick, underlies Lyons Landings and Maine Sunrise River valleys. Limestone and dolomite (Qcd) 40, 220 ft. thick, underlies Bald Knob. Glacial-lacustrine sands, generally about 150 ft. thick, though sands within them may be about 200 ft. thick, underlie about 25 sq. mi. in the Lyons Landings and Maine Sunrise River valleys. Bedrock: Pottsville sandstone of Mifflin Formation (Pmf) and Lower Kittanning and Mahaffey Members of Allegheny Formation (Pal), 200 ft. thick, underlies all of area. Limestone and marl (Qml) 5 to 20 ft. thick, underlies Lyons Landings and Maine Sunrise River valleys. Limestone and dolomite (Qcd) 40, 220 ft. thick, underlies Bald Knob. Alluvial plains of the Maine Sunrise River and its tributaries, consisting of sand, silt, and clay, plastered to glacial tills and bluffs. Lyons, reworked, alongwall silt of windblown sand plastered to glacial tills and bluffs.	Bearing Value: Poor on clayey silty soils within a few feet of surface. Settlement: Poor to fair, compressible, subsidence. Drainage: Poor to fair, poorly drained, high water table. Slope Stability: Poor to fair, poorly drained, high water table. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Poor to fair, poorly drained, high water table. Bedrock: Fair to good in sandstone and limestone.	Base to provide soils and bedrock on not clean-cut boundaries, mainly compaction sliding, support to proposed alignment. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Clayey silty soils and bedrock on not clean-cut boundaries, mainly compaction sliding, support to proposed alignment. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Sands in lenses unconsolidated water-bearing zones of sand and silt. Clayey silty soils and bedrock on not clean-cut boundaries, mainly compaction sliding, support to proposed alignment. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Subsurface exploration should be carried out to determine depth to water table. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Clayey soils Sandy soils	1,000 - 5,000 where dry 1,000 - 4,000 1,000 - 4,000 where wet 2,000 - 4,000
5	Silty, massive sandy loam with imperfectly developed subsoil of clay loam, and silty clay loam (Qsl) and clay (Qsc) in Lyons Landings and Maine Sunrise River valleys, and Bald Knob. Alluvial sands (Qal) 15 to 30 ft. thick, underlies all of area. Glacial-lacustrine sands (Qgl) and clays (Qgc) 100 ft. thick, underlies Lyons Landings and Maine Sunrise River valleys. Bedrock: Pottsville sandstone of Mifflin Formation (Pmf) and Lower Kittanning and Mahaffey Members of Allegheny Formation (Pal), 200 ft. thick, underlies all of area. Limestone and marl (Qml) 5 to 20 ft. thick, underlies Lyons Landings and Maine Sunrise River valleys. Limestone and dolomite (Qcd) 40, 220 ft. thick, underlies Bald Knob. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Bearing Value: Poor on clayey and silty soils within a few feet of surface. Settlement: Poor to fair, compressible, subsidence. Drainage: Poor to fair, poorly drained, high water table. Slope Stability: Poor to fair, poorly drained, high water table. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Poor to fair, poorly drained, high water table. Bedrock: Fair to good in sandstone and limestone.	Base to excavate soils and bedrock on not clean-cut boundaries, mainly compaction sliding, support to proposed alignment. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Sand available in fill and fine aggregate in soil. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Clayey sand or soils and underlying bedrock, mainly compaction sliding, support to proposed alignment. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Subsurface exploration should be carried out to determine depth to water table. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Shale with sandstone with limestone and marl	3,000 - 7,000 3,000 - 12,000 3,000 - 20,000
6	Gravel, sand limestone and marl, and bedrock generally on upland areas. Limestone and marl (Qml) 5 to 20 ft. thick, underlies about 10 sq. mi. in the Lyons Landings and Maine Sunrise River valleys. Limestone and dolomite (Qcd) 40, 220 ft. thick, underlies about 10 sq. mi. in the Bald Knob area. Bedrock: Pottsville sandstone of Mifflin Formation (Pmf) and Lower Kittanning and Mahaffey Members of Allegheny Formation (Pal), 200 ft. thick, underlies all of area. Limestone and marl (Qml) 5 to 20 ft. thick, underlies Lyons Landings and Maine Sunrise River valleys. Limestone and dolomite (Qcd) 40, 220 ft. thick, underlies Bald Knob. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Bearing Value: Poor on clayey and silty soils within a few feet of surface. Settlement: Poor to fair, compressible, subsidence. Drainage: Poor to fair, poorly drained, high water table. Slope Stability: Poor to fair, poorly drained, high water table. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Poor to fair, poorly drained, high water table. Bedrock: Fair to good in sandstone and limestone.	Base to excavate soils with gravel and gravel deposits, mainly compaction sliding, support to proposed alignment. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Sand limestone and gravel available for construction and sand and gravel for fill. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Layers and lenses of limestone, gravel and sand, and bedrock on not clean-cut boundaries, mainly compaction sliding, support to proposed alignment. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Subsurface exploration should be carried out to determine depth to water table. Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone. Slope Stability: Unconsolidated materials: Poor to fair, compressible and subsidence. Bedrock: Fair to good in sandstone and limestone.	Limestone and marl	6,000 - 21,000 where dry 14,000 - 21,000

SECRET

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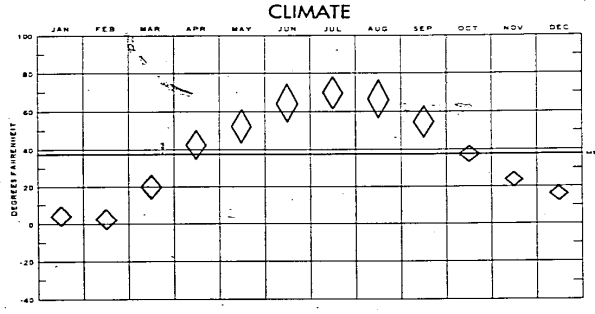
SECRET

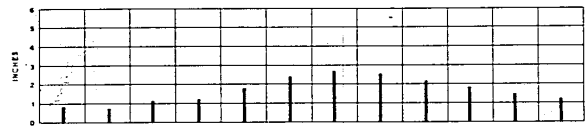
CLIMATE



MONTHLY TEMPERATURES

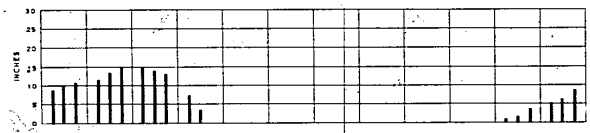
MEAN DAILY MAXIMUM
MEAN TEMPERATURE
MEAN DAILY MINIMUM
ABSOLUTE MAXIMUM TEMP.
ABSOLUTE MINIMUM TEMP.

MEAN ANNUAL TEMPERATURE 39.2°F

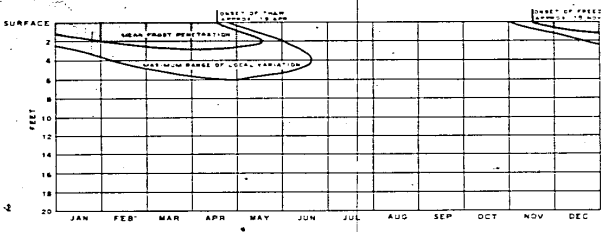


MEAN MONTHLY PRECIPITATION

MEAN ANNUAL PRECIPITATION 19.3 INCHES

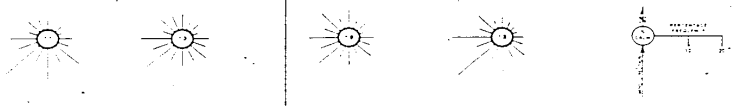


MEAN SNOW DEPTHS
(BY 10-DAY PERIODS)



FROST DEPTHS

SURFACE WIND DIRECTIONS



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